A 316 Demonstration in Support of the
Application for Alternate Effluent Limitations

for the

Potomac Electric Power Company
Dickerson Steam Electric Station

Volume III

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A 316 Demonstration in Support of the Application for Alternate Effluent Limitations for the Potomac Electric Power Company Dickerson Steam Electric Station

Volume III

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Division of Limnology and Ecology
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V. 316(b) STUDIES

V-A. FISH IMPINGEMENT

Introduction

The protection of fish from excessive mortality or damage from power plant intake structures is required by paragraph 316(b) of the Clean Water Act of 1977 (Public Law 95-217). In Maryland, impingement control is under the purview of paragraph F of State of Maryland Regulation .13 Water Quality Impact Assessment for Thermal Discharge under COMAR 08.05.04 Water Pollution Control. That section of the Maryland regulation concerning fish impingement outlines procedures for determining the monetary value of fish loss.

Two impingement studies have been conducted by the Academy of Natural Sciences at the Dickerson SES. The first was initiated in May of 1976 (ANSP, 1978). The effort, entailing one collection each in May, August and November of 1976 and two collections in March of 1977, was a cursory investigation of the species, numbers and general condition of fish being impinged by the plant. The study was designed to investigate possible serious impacts which would warrant further, more rigorous, investigation. No estimate of monthly, seasonal or annual quantities of impinged fish were made during this study, nor were any estimates made of the monetary value of destroyed fish during impingement.

The 1976-77 impingement study indicated the possibility of high impingement levels during spring; therefore, in 1978 another study, entailing a 24-hr collection period every 2 weeks from January 31 to December 20, was conducted. Estimates were made of daily, monthly, seasonal and annual quantities of impinged fish. An estimate of the monetary value of the fish destroyed by impingement was made in accordance with State of Maryland guidelines set forth in Regulation .13 under COMAR 08.05.04 and COMAR 08.02.09.01, Monetary Value of Tidal and Non-Tidal Water Aquatic Animals. In order to more meaningfully interpret the impingement data, it was helpful to relate the numbers of fish impinged to the local fish populations in the river, specifically that community from which fish are drawn into the plant intake (referred to as the pre-impingement community). Therefore, during selected impingement sampling periods, fish were monitored (using minnow traps) in the river in the area of the intake structure. It was hoped that data on the distribution and abundance of fish in the vicinity of the intake structure, supplemented by temperature, turbidity and withdrawal rate data, would make possible a determination of the factors controlling the magnitude of impingement. A comparison of impingement data with data from the pre-impingement trapping results has provided information on the nature of intake selectivity and the relationship between distribution and impingement.

1976-77 Study

Methods

Samples of impinged fish were taken quarterly according to the schedule presented in Table V-A-1 and as described in detail in ANSP, 1978. Initial sampling (May) was carried out by stopping the circulating screens and allowing fish to accumulate for 3 to 8 h. Screens were then backwashed individually and impingement estimates were made for each screen separately. This method proved unsatisfactory because of the large differences in total accumulation time for each screen, so screens were run continuously during subsequent sampling periods.

Collections were made in the trough that transports backwash water to the discharge canal. One-quarter-inch mesh nets of the same dimensions as the trough cross-section were used to filter the backwash water during designated sampling periods. After the fish were collected, they were identified, counted and weighed. Their general condition was noted and recorded. All data were normalized by expressing the number and weight of impinged fish in terms of hourly and daily rates.

Results

Tables V-A-2 and V-A-3 summarize the number of fish impinged by species per day and the weight by species (biomass) per day for the four months in which collections were made. Table V-A-4 gives the water temperature at the time of each collection. Levels were generally low until the March 8-9 sample. Table V-A-2 shows a tremendous increase in the number of spottail shiners *(Notropis hudsonius)* impinged at that time. As a result, another collection was made during the period of March 17-19. During the second collection the numbers of impinged spottail shiners decreased from the March 8-9 levels by a factor of 10, but were still more than 200 times greater than impingement levels during the May, August or November collections.

Although the increased impingement of spottail shiners in March was apparent at all times of day, it was particularly evident in the dusk collections. As dusk collections were not incorporated into the sampling regime until March, the extent to which time of day contributed to increased impingement levels cannot be estimated. If there is a natural pattern of higher impingement at dusk during other seasons, the contrast between impingement levels in March and those in May, August and November may have been exaggerated.

The only other incidence of high impingement was channel catfish (*Ictalurus punctatus*) during the August sample. At that time 193 channel catfish fingerlings per day were impinged.

Since this was a cursory study and no supplementary data were collected, the cause of the increased impingement of these species was not determined.

Table V-A-1. Sampling schedule for the impingement study at the Dickerson SES, 1976-1977.

Date	Time	Day/Night/Dusk	Number of Samples	Duration of Samples
May				
17		Day	1	3-8 h accumulation
		Night	1	3-8 h accumulation
18		Day	1	3-8 h accumulation
21		Night	1	3-8 h accumulation
Aug.				
3		Day	3	30 min
		Night	3	30 min
4		Day	3	30 min
		Night	3	30 min
Nov.				
19		Day	3	15 min
		Night	3	15 min
20		Day	3	15 min
		Night	3	15 min
Mar.				
8		Day	3	30 min
		Dusk	1	30 min
		Night	2	15 min
9		Day	3	30 min
		Dusk	1	15 min
		Night	2	15 min
17	1900	Dusk	3	5 min
18	0700	Day	3	5 min
	1000	Day	3	5 min
	1400	Day	3	5 min
	1600	Day	3	5 min
	1900	Dusk	3	5 min
19	2200	Night	3	5 min
	0100	Night	3	5 min
	0400	Night	3	5 min

Table V-A-2. Estimated impingement levels (numbers of individuals/day) by species for the Dickerson SES impingement study, 1976-1977 (ANSP, 1978).

Species	Mean Number of Fish/Day (estimated)			
	May	August	November	March [1]
Goldfish	17.6	0	6.0	0
Spottail shiner	21.6	4.2	0	6,414.9 [2]
Spotfin shiner	38.6	37.0	0	11.9
Redhorse	22.0	14.8	0	7.2
Channel catfish	8.2	193.2	0	42.2
Margined madtom	4.8	4.0	8.4	3.4
Redbreast sunfish	10.6	5.6	8.4	7.5
Green sunfish	0	0	0	2.0
Pumpkinseed	24.0	0	0	13.5
Bluegill	5.8	0	0	56.2
White crappie	0	0	0	14.2
Black crappie	4.8	0	0	1.0
Undet. Cyprinidae	5.8	9.6	0	0
Undet. Centrarchidae	7.6	0	0	1.0
Undet. Darters	0	0	0	12.5
TOTAL	171.4	268.4	22.8	6,589.5

[1] Average for both trips
[2] March 8-9 = 11,513.8
March 17-19 = 1,316.1

Table V-A-3. Estimated impingement levels (grams/day) by species for the Dickerson SES impingement study, 1976-1977.

Species	Mean Number of Grams/Day (estimated)			
	May	August	November	March[1]
Goldfish	2,754	0	40	0
Spottail shiner	108	56	0	32,027[2]
Spotfin shiner	198	190	0	57
Redhorse	3,156	350	0	109
Channel catfish	234	1,554	0	468
Margined madtom	34	40	224	23
Redbreast sunfish	140	196	0	765
Green sunfish	0	0	0	20
Pumpkinseed	1,068	0	0	144
Bluegill	260	0	0	336
White crappie	0	0	0	103
Black crappie	300	0	0	5
Undet. Cyprinidae	90	248	0	0
Undet. Centrarchidae	378	0	0	21
Undet. Darters	0	0	0	34
TOTAL	8,720	2,634	264	34,112

[1]Average for both trips

[2]March 8-9 = 58,264; March 17-19 = 5,789

Table V-A-4. Daily average river temperature on impingement sampling dates, Dickerson SES. (Data provided by PEPCO.).

Date			$\bar{X}$ T (°C)
1976	May	17	21.1
		18	20.0
		19	21.1
	Aug.	3	24.4
		4	23.3
	Nov.	19	7.2
		20	7.8
1977	Mar.	8	6.7
		9	7.2
		17	10.0
		18	10.0
		19	9.4

1978 Study

Methods

Impingement

Sampling began on January 31 and continued through December 20, 1978 (Table V-A-5). Collections, made every two weeks, consisted of eight 1-h continuous samples every 3 h for a period of 24 h. For some of the early collections, additional dawn and dusk 1-h samples were taken. Samples were taken from the backwash trough, as in the cursory study, with 1/4-in mesh nets of the same dimensions as the trough. All fish were identified and counted. Length and weight measurements were recorded. Fish weighing 5 g or less and less than 10 cm in length were weighed as a group, but individual lengths were recorded. When more than 50 individuals of a species of small fish were collected, the lengths and total combined weight of 50 randomly-selected individuals were recorded.

Daily estimates (D est) were calculated by multiplying the hourly mean (sum of total or selected species collected after impingement in a 24-h period divided by the number of samples taken) by 24 h. The following formula was used for the calculations:

$$D\ est = \frac{\Sigma f_{24}}{S_{24}}\, 24$$

in which Σf_{24} is the sum of fish collected after impingement in a 24-h period and S_{24} is the number of samples taken in that 24-h period.

Monthly estimates (M est) were calculated by first determining a mean number of fish per hour over all samples in that month, then multiplying it by 24 h to obtain a daily estimate for that month. Multiplying the daily estimate by the number of days in the month gave the monthly estimate. Calculations were made using the formula:

$$M\ est = \left(\frac{f_m}{S_m}\right)(24)(dm)$$

in which f_m is the actual number of fish collected after impingement for all 1-h sample periods in a given month combined, S_m is the number of 1-h samples taken during that month and dm is the number of days in that month.

Seasonal estimates (S est) were obtained by first determining the mean number of fish impinged per hour over all samples taken during that season. The mean hourly rate was multiplied by 24 to obtain the daily rate for that season. The daily rate

Table V-A-5. Sampling schedule for the impingement and pre-impingement studies at the Dickerson SES, 1978.

Impingement	Pre-impingement
January 31 - February 1	
February 15-16	
March 9-10	
March 28-29	
April 6-7	
April 18-19	+
April 25-26	
May 9-10	
May 24-25	+
June 7-8	
June 21-22	+
July 5-6	
July 19-20	
July 31 - August 1	
August 15-16	
August 29-30	+
September 12-13	
September 26-27	+
October 11-12	
October 23-24	+
November 7-8	
November 20-21	+
December 5-6	
December 19-20	+

was multiplied by the number of days in the season to obtain the seasonal estimates. Calculations were made using the formula:

$$S\ est = \left(\frac{f_s}{S_s}\right)(24)(d_s)$$

in which f_s is the actual number of impinged fish collected during all 1-h sampling periods in a given season combined, S_s is the number of 1-h samples taken in that season and d_s is the number of days in that season. Inclusive dates of the seasons used in the analysis of impingement data are:

Winter:	December 22 - March 21
Spring:	March 22 - June 21
Summer:	June 22 - September 21
Fall :	September 22 - December 21

Annual impingement (A est) was estimated by totaling the four seasonal impingement rates. The formula:

$$A\ est = \Sigma\ S\ est$$

describes the calculations.

Unit costs for each group of economically valuable fish were obtained from the State of Maryland regulations. For each sample taken, the cost is determined for each length class in each of the fish groups. This is the product of the number of fish in the group, the percentage of that total comprising the length class and the cost for a fish of that size in that group. The total dollar amount for each fish category is then averaged over each month yielding an hourly cost per month. These monthly costs are then multiplied by the number of hours in each month and summed to give the yearly cost estimate for each fish group.

Water temperature and turbidity were measured to determine possible correlations with numbers of fish impinged. Water temperatures were obtained from the plant-operated thermographs, which recorded the temperature of water upon withdrawal from the river. Turbidity at the intake structure was measured with a Hach 2100 turbidometer. Supplementary turbidity measurements for the Monocacy River were obtained from the United States Geological Survey.

Plant operating data are also included for analysis; of particular interest is the operation schedule for the circular pumping units (see Plant Operating Data, Section II of this report, for a description of the cooling water pumping system).

Pre-Impingement

To determine the relative abundance and distribution of fish in the river in the general vicinity of the SES and in the immediate area of the intake structure, 63 minnow traps (Fig. V-A-1) (61cm long, 27cm in diameter, with 5-cm openings) were deployed in the area from 260m above to 165m below the intake structure as shown in Figure V-A-2. Forty-five traps were designated "river traps" and were placed directly on the bottom near both banks and every 75m along five transects crossing the river. Eighteen traps were placed in two rows directly in front of the intake; six traps suspended on the surface, six suspended at mid-depth and six resting on the bottom. Preliminary studies indicated that surface and mid-depth traps were ineffective when used along river transects, perhaps because the current was too strong there. Consistent trap locations were maintained for all sampling dates by establishing permanent marker buoys along the transects. In this way the pre-impingement data for all periods were determined to be comparable.

The traps were fabricated specifically for this study because the volume and openings of commercially available minnow traps were too small. Larger minnow traps were determined to be appropriate because they would be more efficient for collecting the size group of the most numerous species of fish impinged by the plant, as determined by the 1976-77 study (ANSP, 1978). *Notropis hudsonius*, the most common fish impinged, ranged from 7 to 10cm in length, averaging 9cm. *Ictalurus punctatus* were about 10cm long, and the *Lepomis* were from 5 to 9cm long.

A preliminary study indicated that traps baited with raw chicken necks were more effective than unbaited traps or traps baited with a "dough" type bait that eventually disintegrated completely. Since the bait remained in the traps for the entire period of deployment, fish were attracted for the entire 24-h sampling period.

Traps were deployed for 24 h to coincide with the dates of eight of the impingement studies (Table V-A-5). Ice in the river and high flows prevented deployment of the traps during the early months of the impingement study. Therefore, no estimates of population sizes in the river could be made during the critical period of high impingement observed in March.

Several short-term studies were carried out to determine the effectiveness of the traps and to indicate the relative abundance of fishes in the area near the intake structure as compared with upstream and downstream areas.

In the first of these supplementary collections, on April 25-26, 1979, 76 traps were placed along the Maryland shore of the river from the confluence of the Monocacy River to a point just downstream from Mason Island. These traps were deployed at

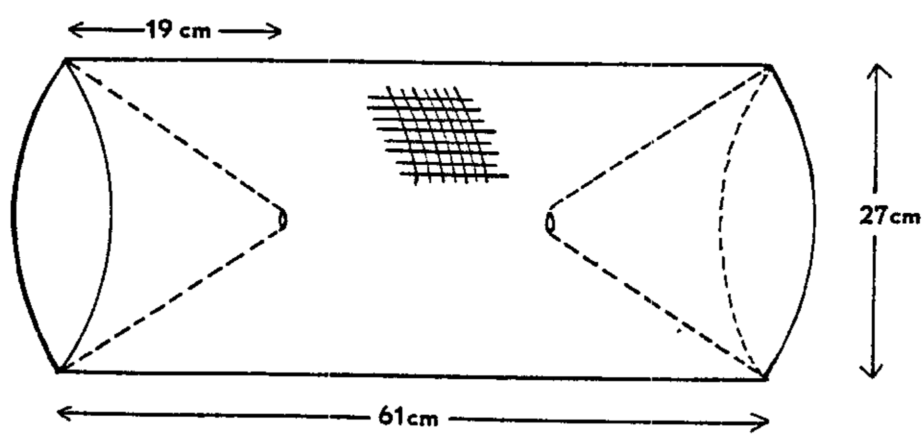


Figure V-A-1. Minnow trap assembly used in the 1978 pre-impingement study at the Dickerson SES.

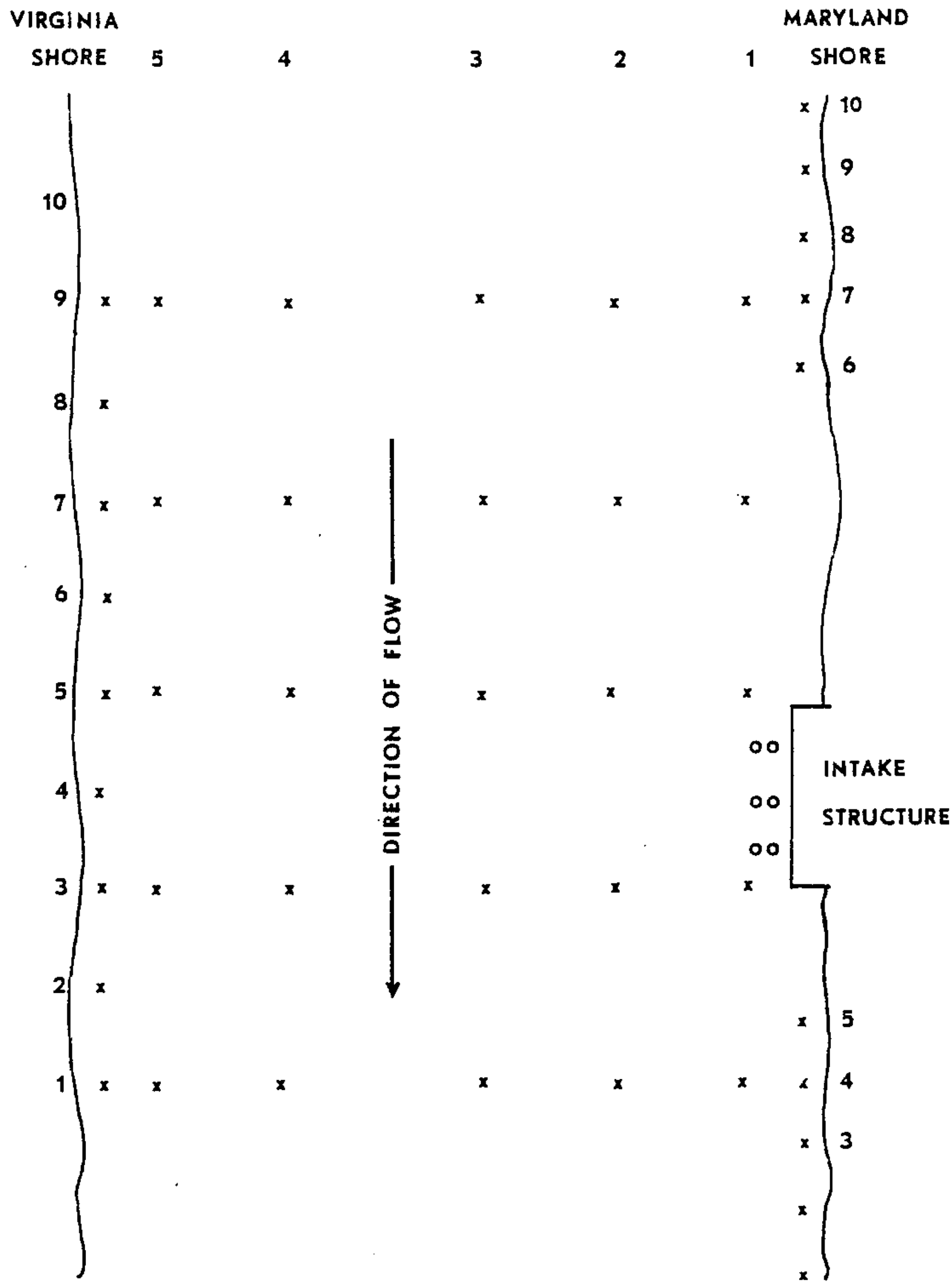


Figure V-A-2. Location of minnow traps during the 1978 pre-impingement study at the Dickerson SES. Locations of traps placed on the bottom are signified by x, locations where traps were placed on the surface, mid-depth and river bottom are signified by o.

90-m intervals as described earlier. At each trap location a measurement was made of water temperature and current (the latter with a Mash-McBirney Electromagnetic current meter). Turbidity was measured at 900-m intervals.

As summer and fall trap collections contained many fewer *Notropis hudsonius* than had been collected in the spring, we attempted to determine if the traps were still collecting effectively. Ten traps were set 30 km downstream at location 20 (Fig. V-A-3), an area where this shiner is known to occur. These traps were set while the November 20-21 pre-impingement study was in progress. They were set near shore using the procedure employed for pre-impingement studies except that they were fished for only 2 h.

The last supplementary study was carried out on December 17-18, 1978. Forty traps (2 per station) were set along the Maryland shore of the Potomac River from the confluence of the Monocacy River to a point 30 km below the plant at locations indicated in Figure V-A-3.

Results

Impingement

Figures V-A-4a through f present the estimated numbers impinged in each 24-h sampling period for: total fish (all species combined); smallmouth bass, channel catfish and sunfish (because they are important sportfish); spottail (because of the large numbers impinged) and spotfin shiners (because they are a major forage fish).

Numbers of fish impinged by month for all species combined, smallmouth bass, channel catfish, sunfish, spottail and spotfin shiners are presented in Figures V-A-5a-f. Impingement estimates by season for the same categories are presented in Figures V-A-6 a-f. Table V-A-6 gives the estimated annual impingement levels for the same categories.

Data on numbers of fish impinged indicate two major peaks, one in March and one in May. Spottail shiners made up 99% of the March peak. The May peak was 41% spottail shiner, 25% combined sunfish species, 9% spotfin shiner and 13% channel catfish. The remaining 12% was made up of 13 species, each impinged in low numbers. Sunfish were impinged in low numbers throughout the year, except during the May peak.

Table V-A-7 gives a breakdown of total fish impinged during the day and night, presented as the mean number of fish per hour sampled. The earliest studies included separate dusk and dawn

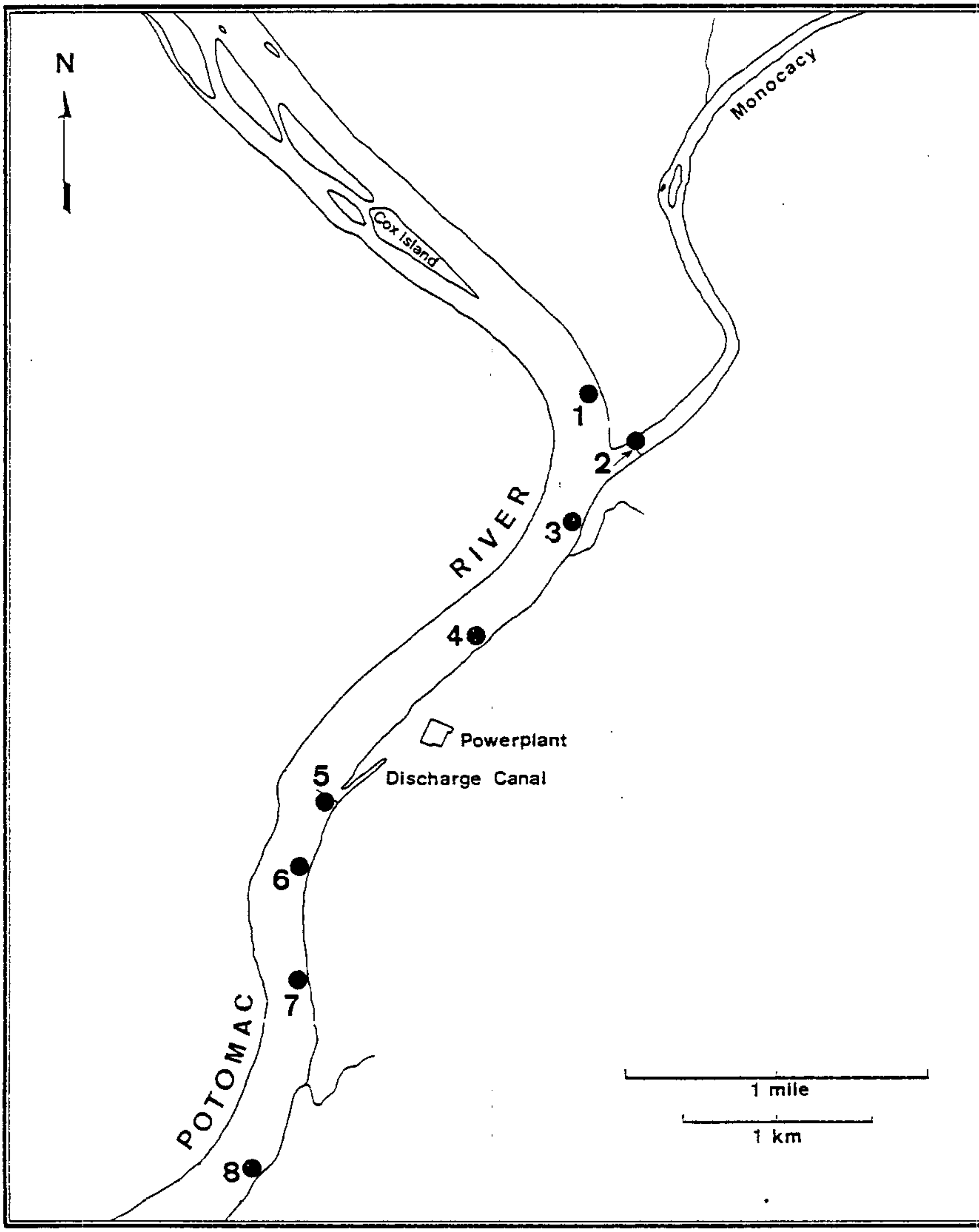


Figure V-A-3. Locations of traps during the linear trap study conducted December 17-18, 1978 in the vicinity of the Dickerson SES.

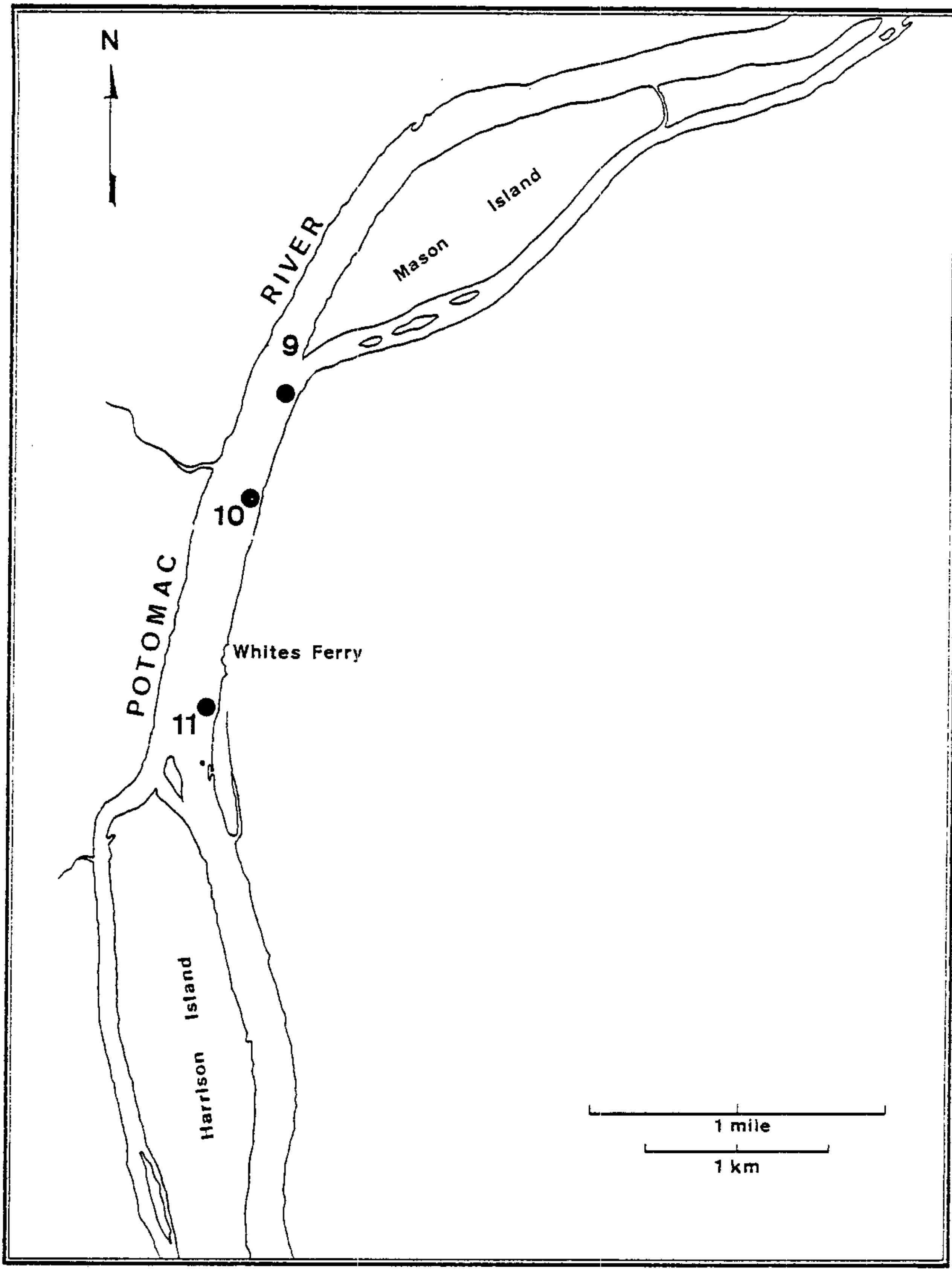


Figure V-A-3 (continued). Locations of traps during the linear trap study conducted December 17-18, 1978 in the vicinity of the Dickerson SES.

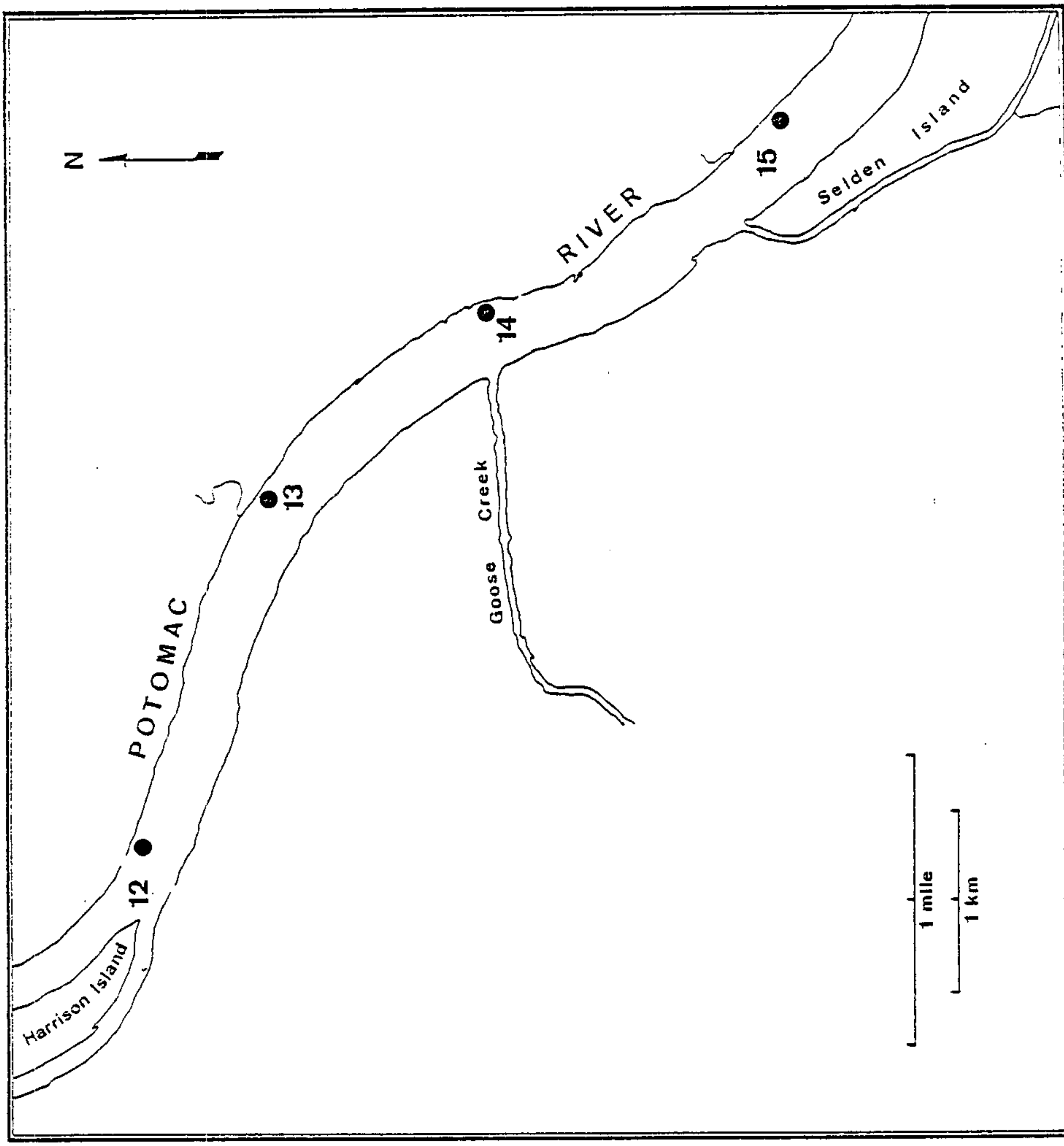


Figure V-A-3 (continued). Locations of traps during the linear trap study conducted December 17-18, 1978 in the vicinity of the Dickerson SES.

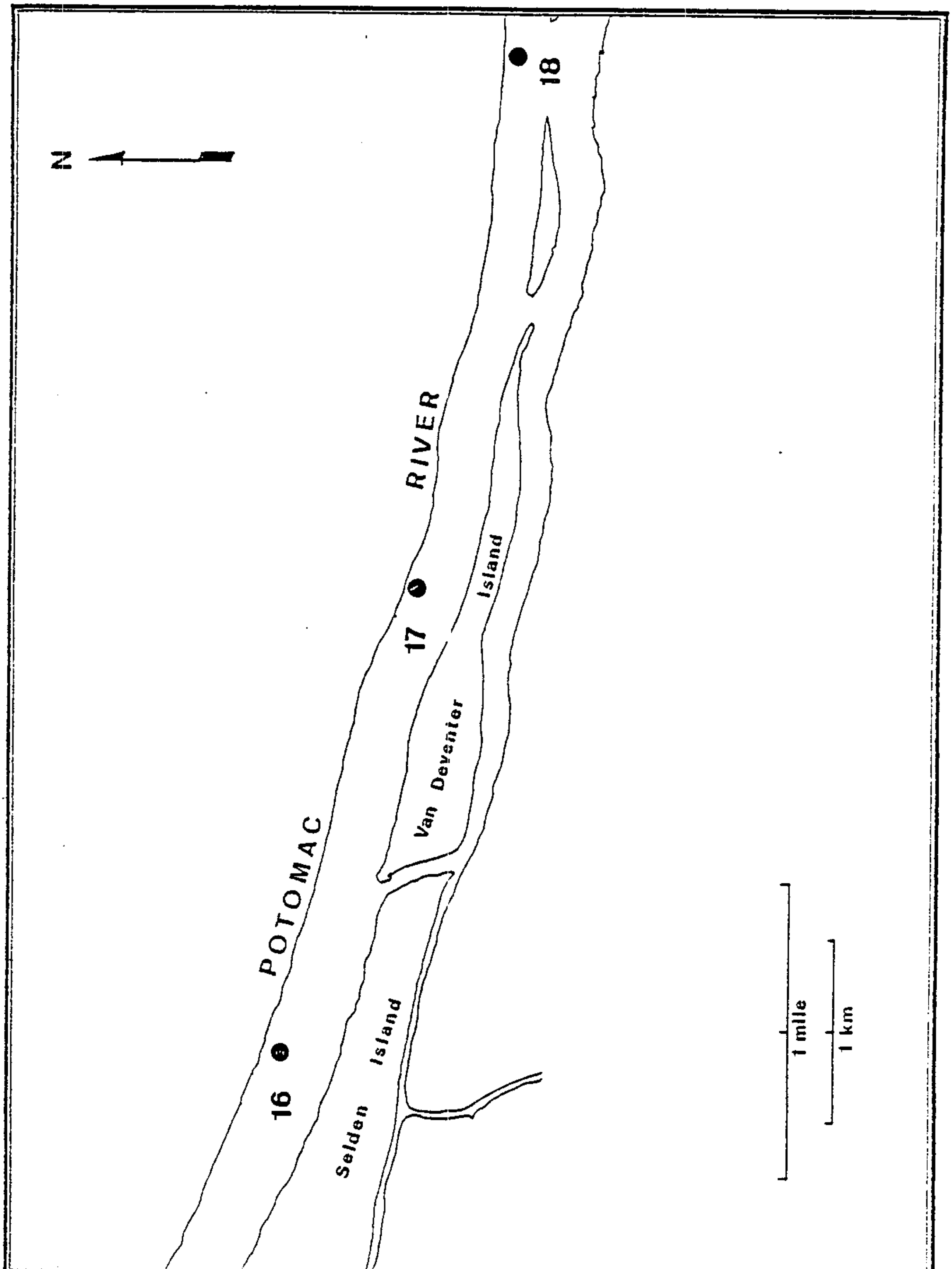


Figure V-A-3 (continued). Locations of traps during the linear trap study conducted December 17-18, 1978 in the vicinity of the Dickerson SES.

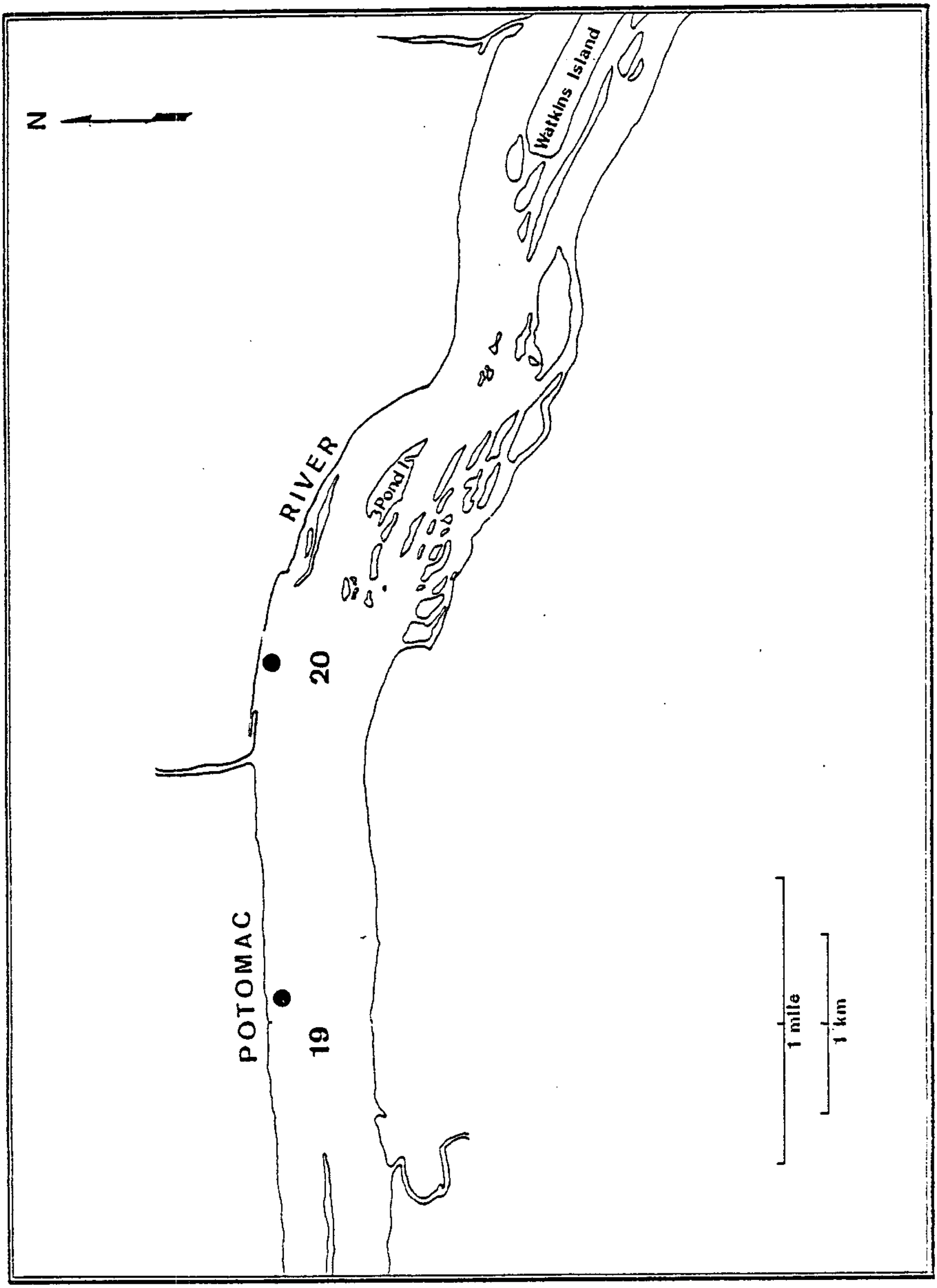
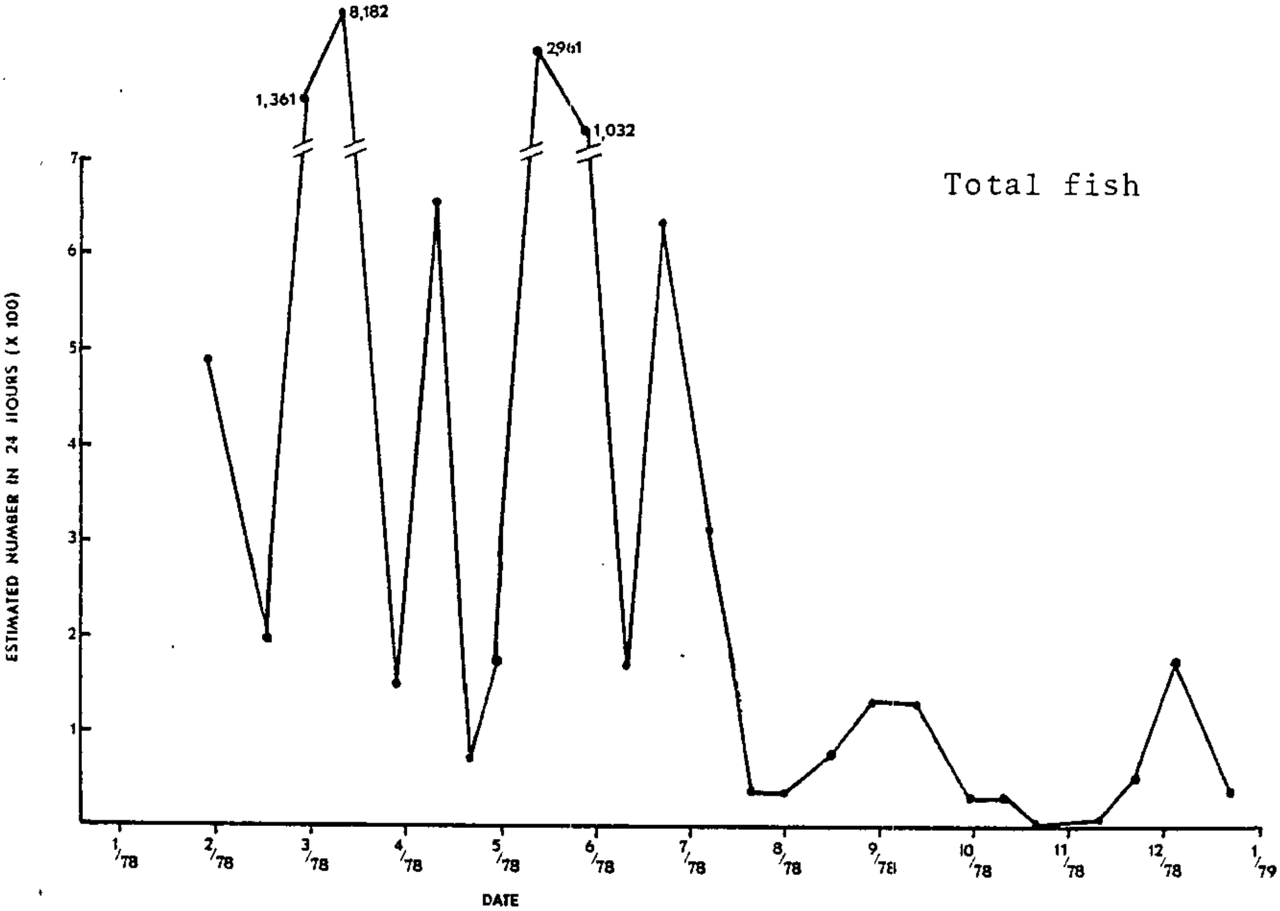


Figure V-A-3 (continued). Locations of traps during the linear trap study conducted December 17-18, 1978 in the vicinity of the Dickerson SES.

a.



b.

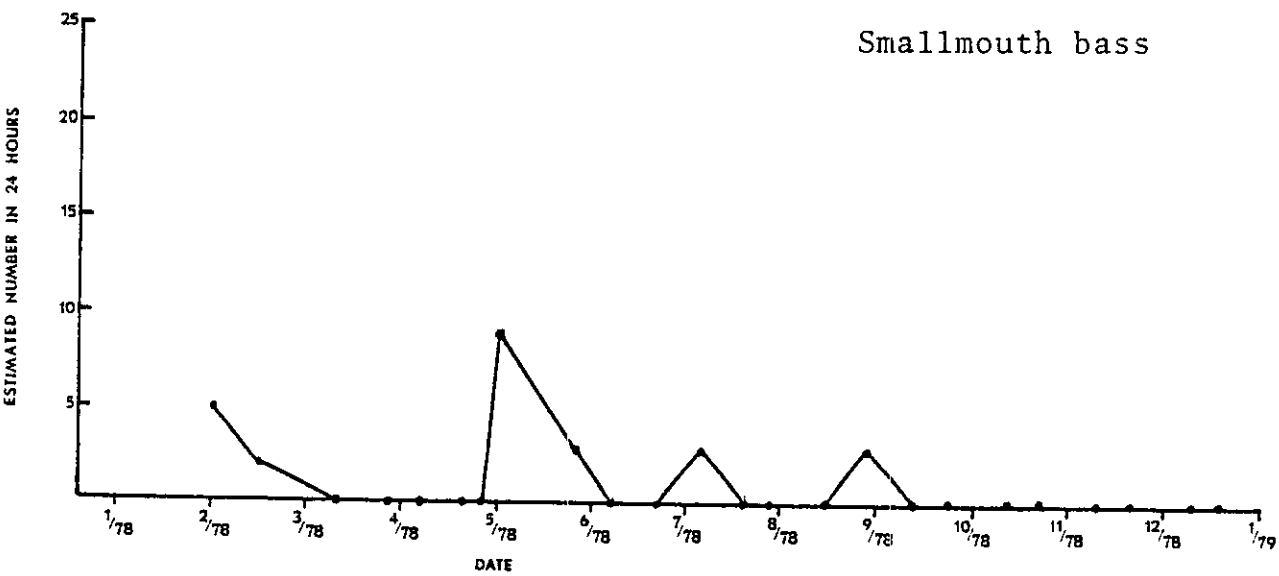
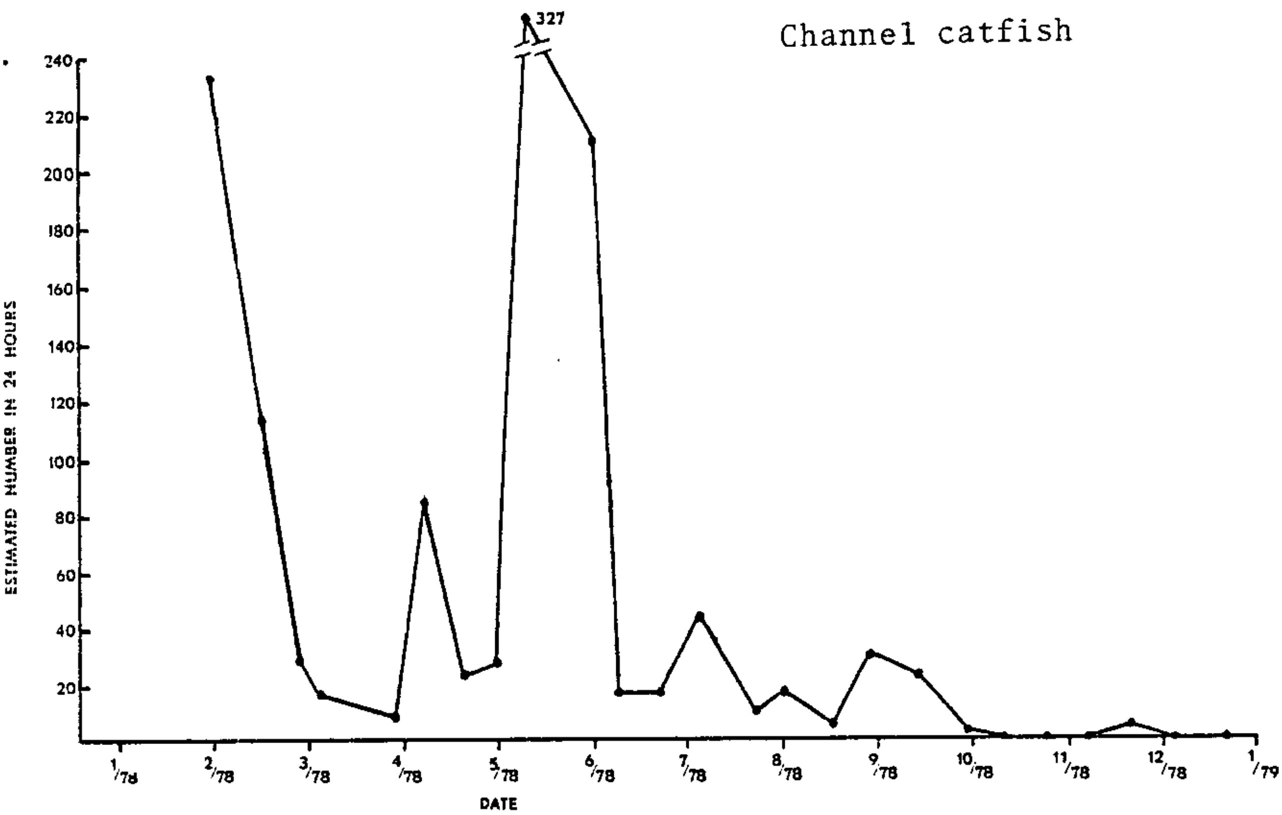


Figure V-A-4. The estimated numbers of total and selected species of fish impinged in a 24-h period at the Dickerson SES during 1978.

c.



d.

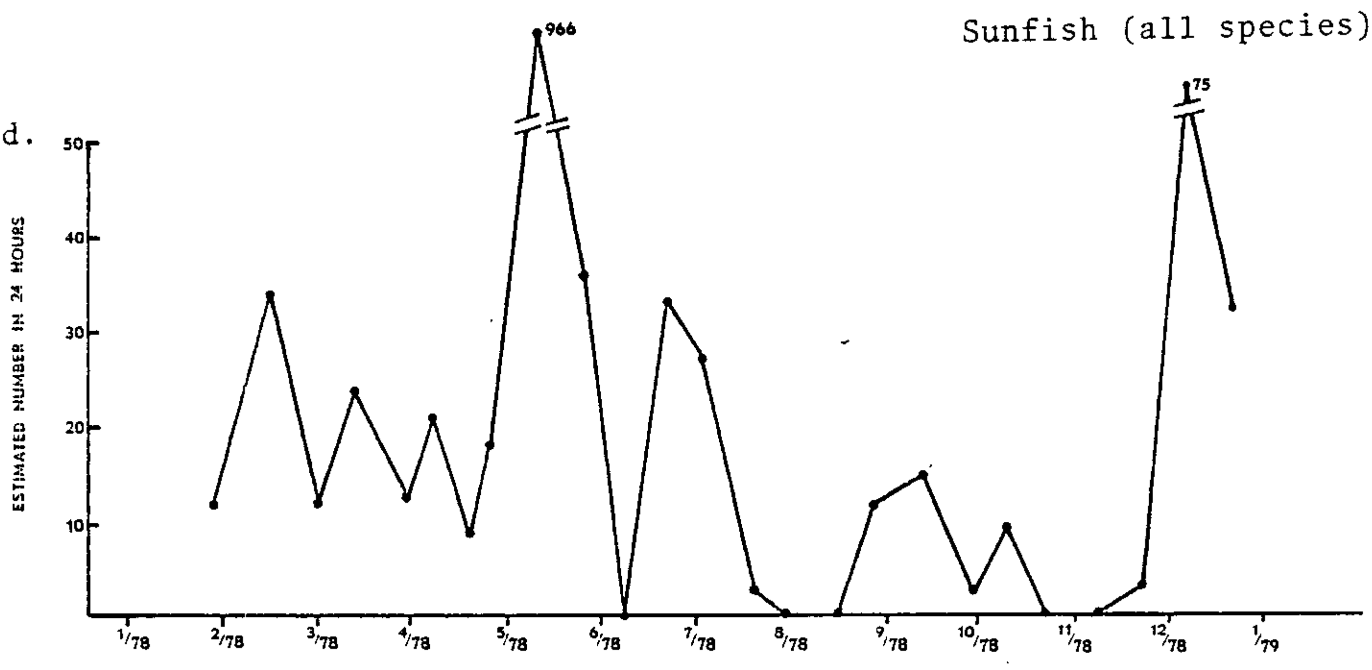
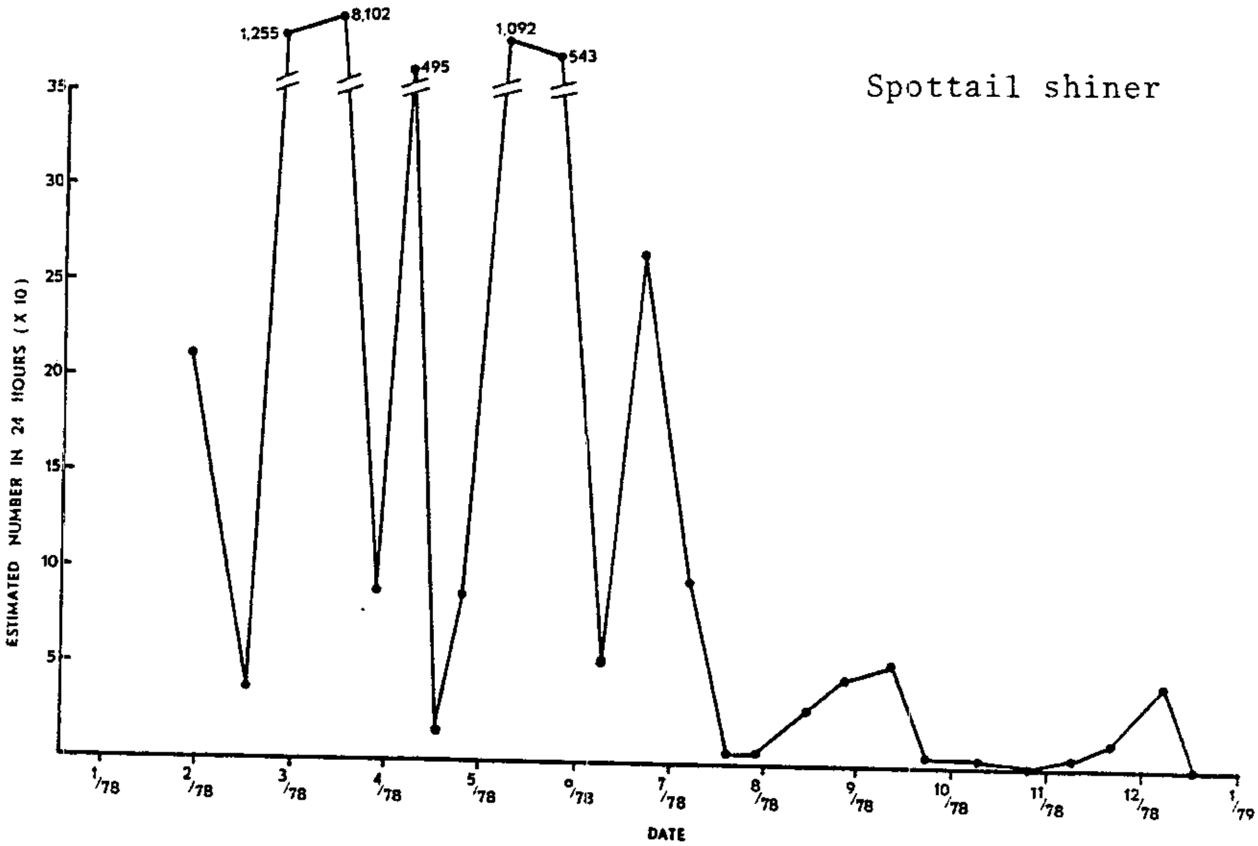


Figure V-A-4 (continued). The estimated numbers of total and selected species of fish impinged in a 24-h period at the Dickerson SES during 1978.

e.



f.

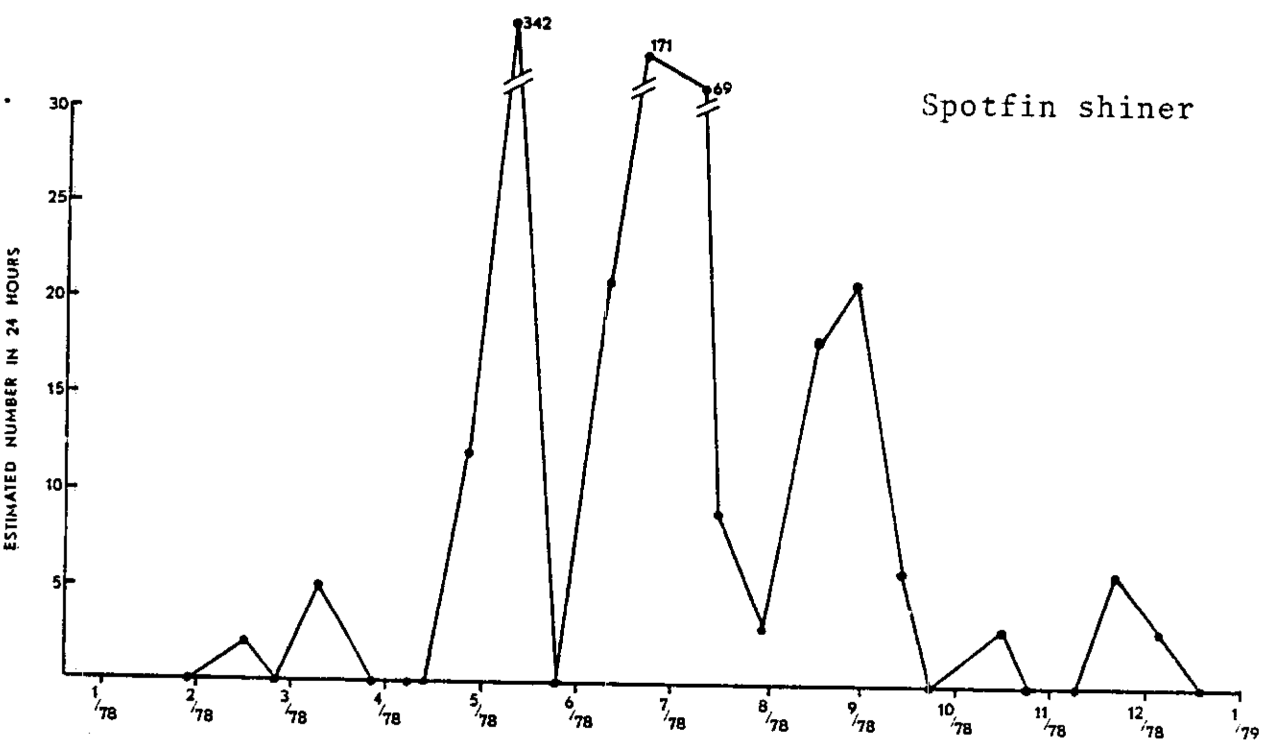
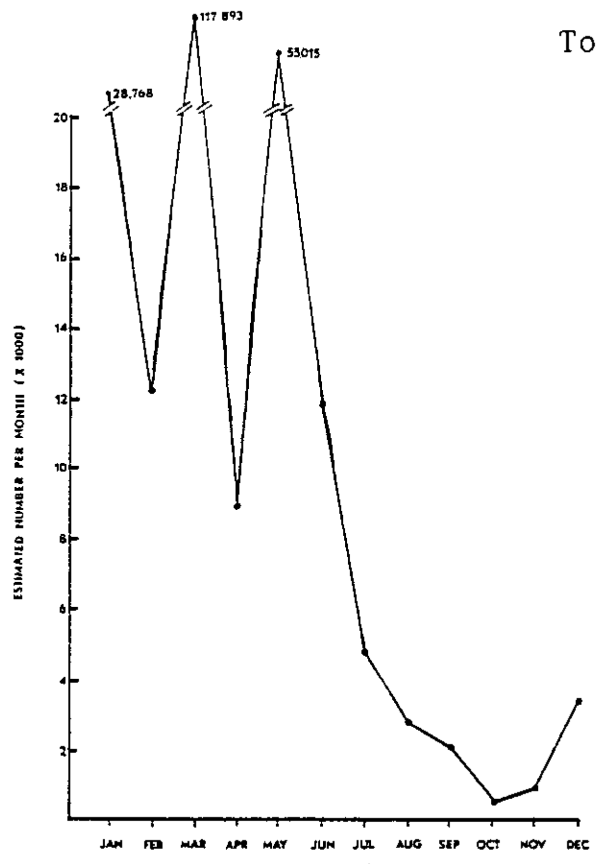


Figure V-A-4 (continued). The estimated numbers of total and selected species of fish impinged in a 24-h period at the Dickerson SES during 1978.

5a.

Total fish



5b.

Smallmouth bass

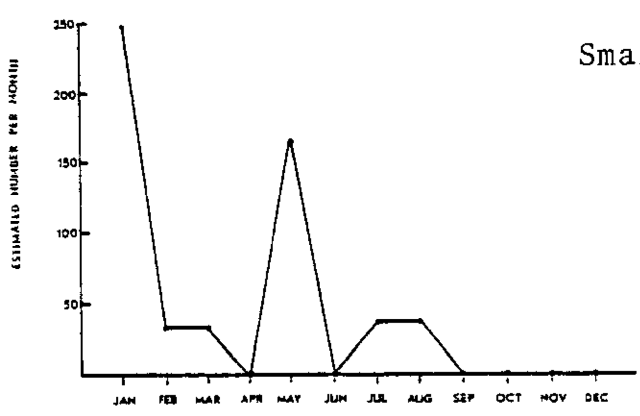
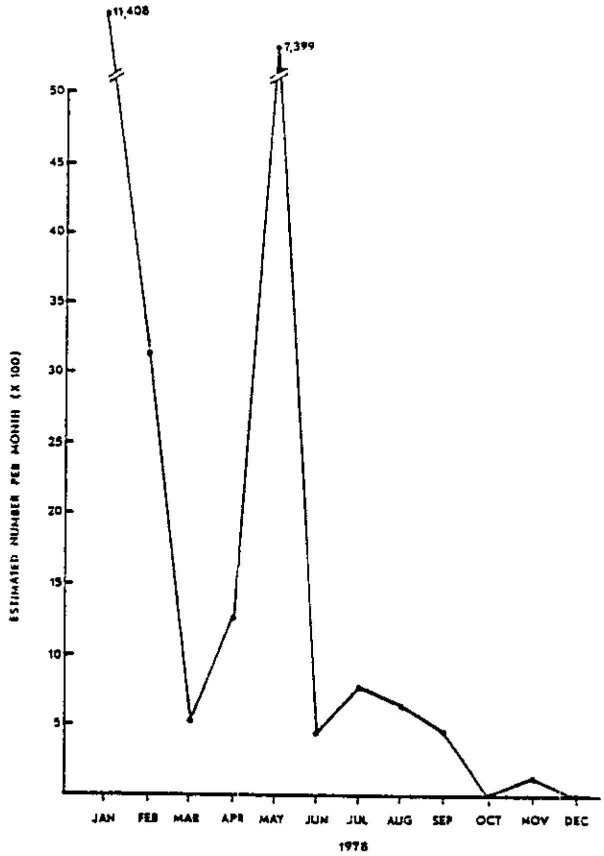


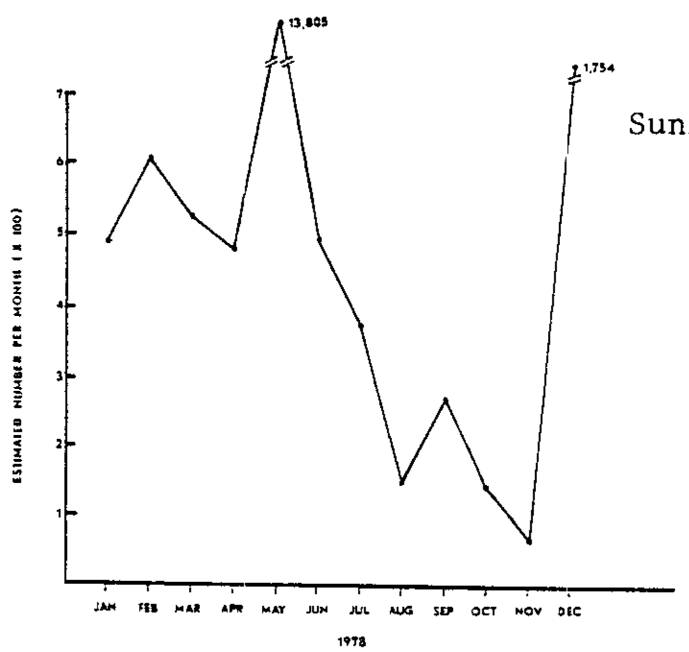
Figure V-A-5. The estimated monthly levels of impingement for total and selected species of fish during the 1978 impingement study at the Dickerson SES.

5c.



Channel catfish

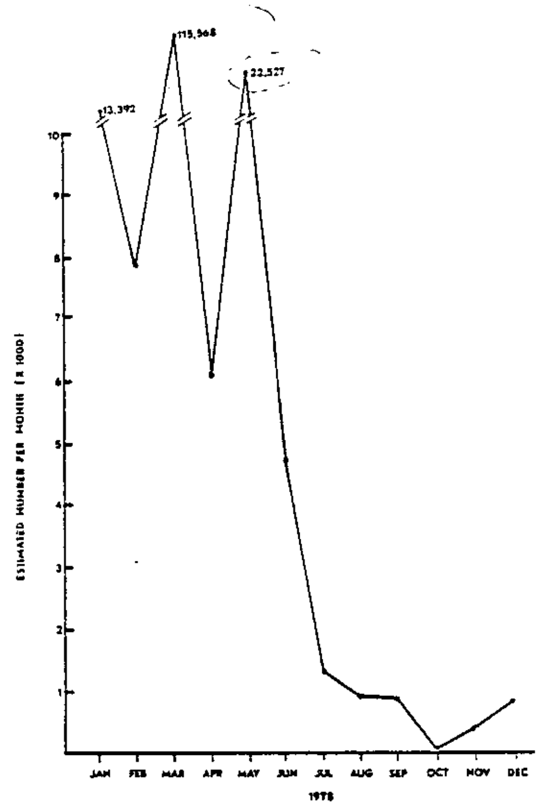
5d.



Sunfish (all species)

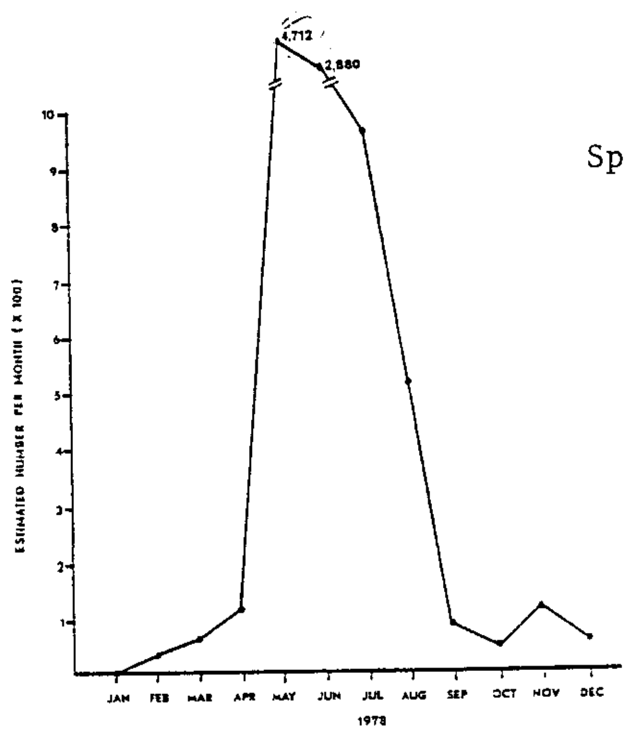
Figure V-A-5 (continued). The estimated monthly levels of impingement for total and selected species of fish during the 1978 impingement study at the Dickerson SES.

5e.



Spottail shiner

5f.



Spotfin shiner

Figure V-A-5 (continued). The estimated monthly levels of impingement for total and selected species of fish during the 1978 impingement study at the Dickerson SES.

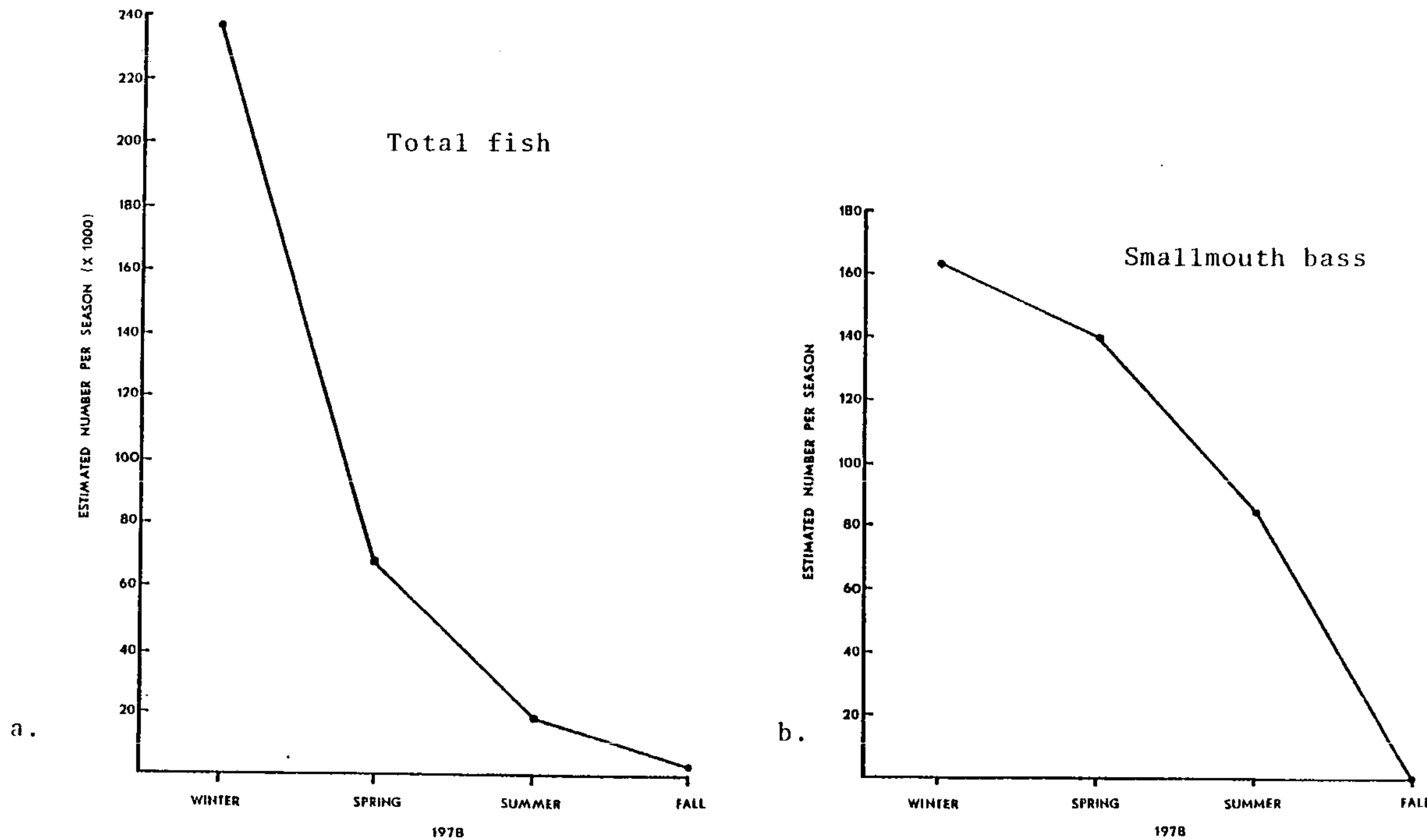
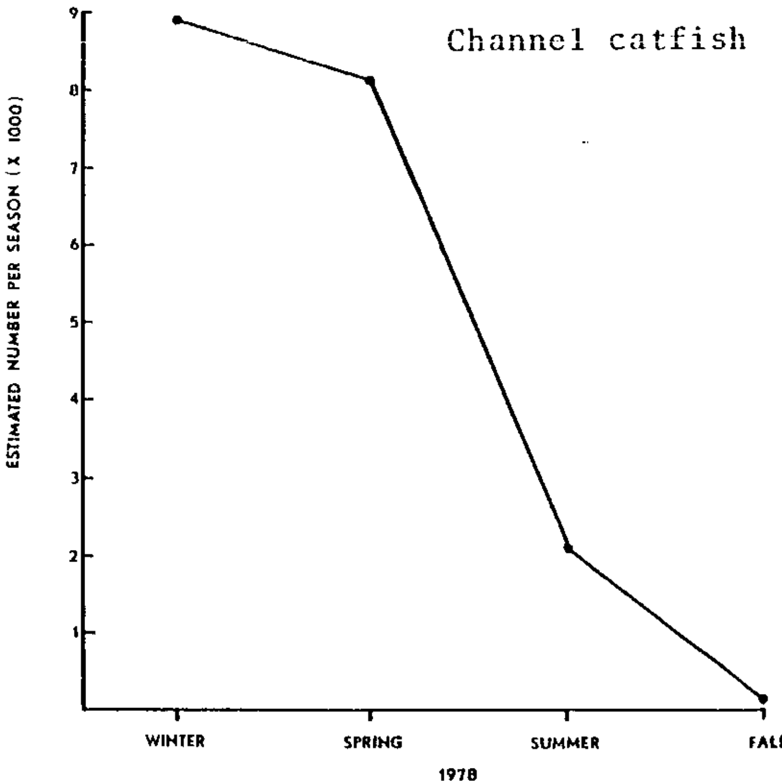


Figure V-A-6. The estimated number of total and selected species of fish impinged during each season of the 1978 Dickerson SES impingement study.

c.



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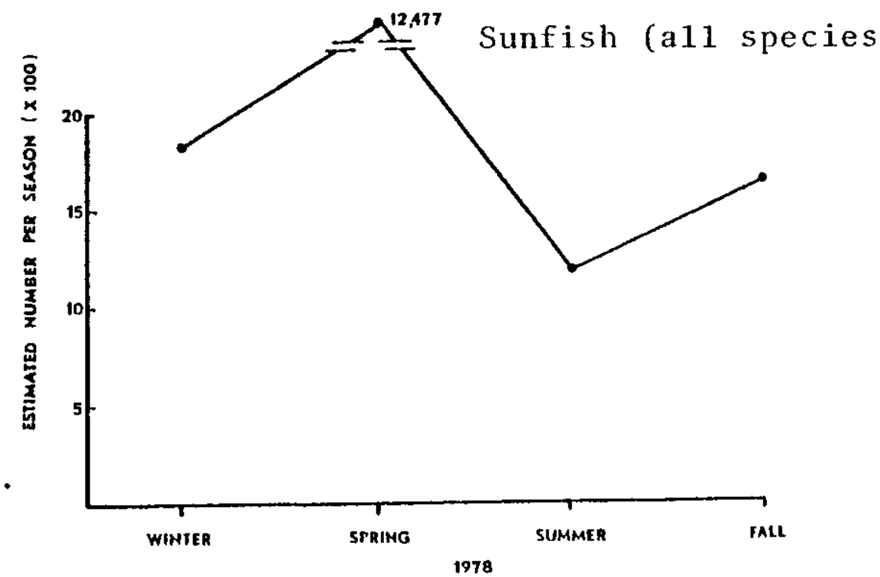
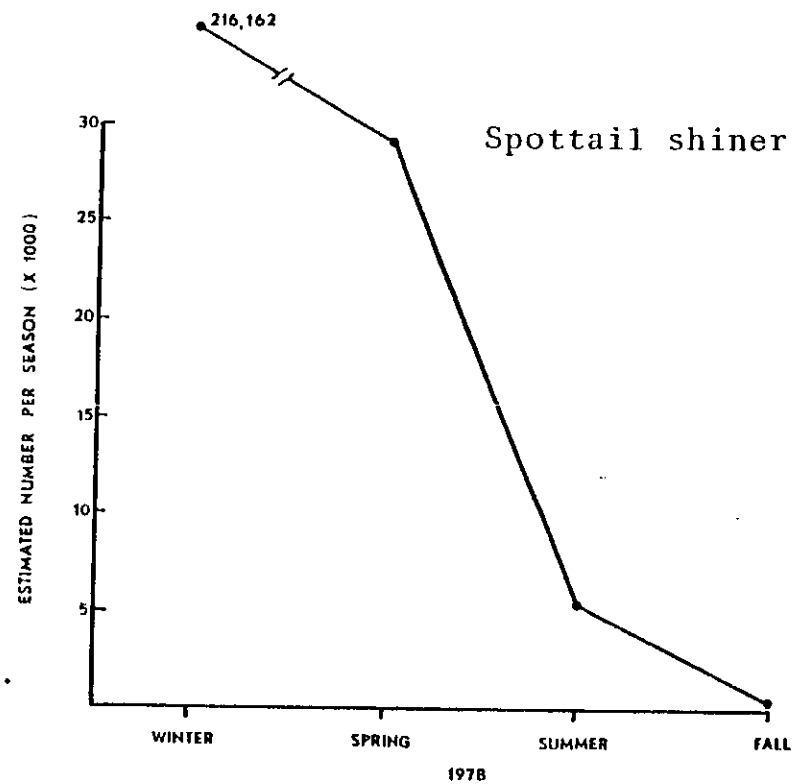


Figure V-A-6 (continued). The estimated number of total and selected species of fish impinged during each season of the 1978 Dickerson SES impingement study.

e.



f.

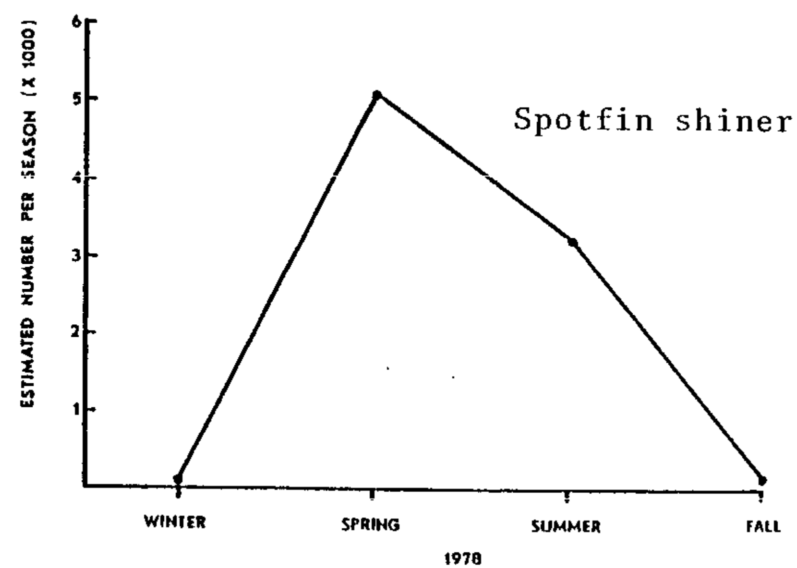


Figure V-A-6 (continued). The estimated number of total and selected species of fish impinged during each season of the 1978 Dickerson SES impingement study.

Table V-A-6. Estimated number of fish impinged during 1978 at the Dickerson SES.

Largemouth bass	33
Smallmouth bass	344
Rockbass	116
Bullheads (all species)	484
Carp	1,183
Channel catfish	16,884
Forage fish	213,230
Crappie (Black and White)	883
American eel	25
Madtoms	751
Yellow perch	30
Suckers and Redhorse (all species)	2,493
Sunfish (all species)	19,656
	256,222

Table V-A-7. Mean number of fish per hour impinged at dusk, dawn, daylight and night during the impingement study at the Dickerson SES, 1978.

Date	Light	Dark	Dawn	Dusk
January 31	12.2	25.	9	48
February 15	3	13.	8	0
February 28	74.2	59.2	23	10
March 9	24.2	781. spottail shiners	158	30
March 28	5.5	7.7	0	1
April 6	14.	41.6	38	0
April 18	1.	5.3	-	-
April 25	2.2	8.2	16	0
May 9	36.	237.	-	58
May 24	28.7	55.7	-	-
June 7	5.	9.6		
June 21	13.4	48.3		
July 5	10.	18.		
July 19	0.6	3.3		
July 31	2.0	0.6		
August 15	2.2	3.6		
August 29	4.6	6.		
September 12	3.8	7.3		
September 26	0.2	1.5		
October 11	0.5	1.2		
October 23	0	0		
November 7	-	0.2		
November 20	1.5	2.5		
December 5	8.2	5.7		
December 19	0	3.0		

samples, which are also included in Table V-A-7. In 20 out of 25 sampling periods, more fish were impinged in the dark than in the light. Dawn or dusk samples were higher than daylight samples for six out of nine sample periods; however, they were higher than the dark samples only twice.

Monthly estimates of the total weights of all species impinged combined, smallmouth bass, channel catfish, combined sunfish, spottail and spotfin shiners are presented in Table V-A-8. Estimates of the weights of fish impinged by season are presented in Table V-A-9. The greatest estimated weight per season was for Spring; the greatest monthly estimated weight was in May.

The sizes of smallmouth bass, channel catfish, combined sunfish, spottail and spotfin shiners for each sampling period throughout the year are presented as mean lengths (Table V-A-10).

Water temperature and turbidity data are presented in Figures V-A-7 and V-A-8c. Turbidity is presented as USGS measurements at Frederick, Md. and measurements made at the SES. Water temperature was taken at the SES intake structure (see Methods section) at the time of sampling. Physical variables are presented to assess possible correlations with quantities of fish impinged. The volume of water taken into the plant at the time of each sample is also shown (Fig. V-A-9). A discussion of the role of intake volume and other physical-chemical variables is presented in the discussion section.

The monetary value of the fish lost because of impingement was determined as prescribed by paragraph F.(1) of the State of Maryland Water Resources Administration's regulation 08.05.04. COMAR 08.02.09.01 presents a list of species and their values according to length. Table V-A-11 presents the monetary value of each species and the total value of all fish estimated to have been impinged during the 1978 study.

Pre-Impingement

The results of the pre-impingement study provided information on the temporal and spatial distribution of fish in the Potomac River in the general vicinity of the SES and in the immediate area of the intake structure. Table V-A-12 summarizes the fish caught at each transect location for each pre-impingement collection period. Two trends are evident. First, the greatest number of fish are distributed along the banks of the river. Second, the trapping data indicate that the fish community appears to have undergone a considerable decrease in size during the course of this study. Figure V-A-8b presents the totals of fish collected in front of the intake structure and those collected in traps from the Maryland side of the river (transect locations MS through 2, Figure V-A-2). The pre-impingement community dropped off to very low numbers by the end of June. Eighty percent of the fish collected in the traps were *Notropis hudsonius*.

Table V-A-8. Estimated total weight (kilograms) by month for fishes impinged during 1978 at the Dickerson SES.

	Weight (Kilograms)					
Month	All Species	Smallmouth Bass	Channel Catfish	Combined Sunfish	Spottail Shiner	Spotfin Shiner
January	624.22	0.99	203.11	15.38	113.34	0
February	147.60	0.50	58.56	8.43	42.43	0.12
March	641.58	1.40	7.53	6.94	575.67	0.16
April	82.35	0	15.84	7.45	8.64	0.72
May	1,280.38	2.40	115.03	182.20	158.84	20.09
June	436.68	0	3.20	5.76	27.14	15.57
July	77.08	2.49	42.41	5.69	8.37	4.50
August	133.55	3.91	45.57	8.67	6.29	1.97
September	123.48	0	23.85	12.11	5.58	0.36
October	56.87	0	0	4.19	0.32	1.63
November	81.84	0	22.74	1.74	2.46	0.48
December	139.7	0	0	42.04	7.07	0.27

Table V-A-9. Estimated total weight (kilograms) by season for fishes impinged during 1978 at Dickerson SES.

	Weight (Kilograms)					
Season	All Species	Smallmouth Bass	Channel Catfish	Combined Sunfish	Spottail Shiner	Spotfin Shiner
Winter	1488.67	3.51	157.90	26.30	1094.04	0.49
Spring	1658.17	2.29	128.81	184.21	177.23	25.91
Summer	417.78	7.30	123.31	32.06	34.52	15.88
Fall	235.29	0	168.60	40.40	8.61	2.10
Total	379991					

Table V-A-10. Mean lengths of smallmouth bass, channel catfish, combined sunfishes, spottail shiner and spotfin shiner impinged at the Dickerson SES during each sampling period in 1978.

Date	Mean Length (cm)				
	Smallmouth Bass	Channel Catfish	Combined Sunfish	Spottail Shiner	Spotfin Shiner
January 31-February 1	10.1	12.2	10.0	10.5	
February 15-16		11.4	8.0	8.4	8.5
February 28	16.0	11.5	8.4	8.8	
March 9-10		10.7	9.1	8.9	7.4
March 28-29		12.6	9.1	8.2	
April 6-7		12.3	8.1	8.5	
April 18-19		12.8	10.0	7.8	
April 25-26		12.8	9.0	8.7	8.1
May 9-10	9.1	11.7	8.7	8.6	7.8
May 24-25	12.0	11.8	7.3	9.2	
June 7-8		9.8		9.1	8.2
June 21-22		8.6	8.5	9.1	8.0
July 5-6	17.5	18.5	8.7	9.4	7.7
July 19-20		17.8	8.4	9.5	7.3
July 31-August 1		13.6		9.3	
August 15-16		18.0		9.3	6.9
August 29-30	21.2	18.7	15.9	9.0	7.2
September 12-13		20.0	13.7	9.5	7.2
September 26-27		9.5	9.5	14.8	
October 11-12			11.1	9.2	7.7
October 23-24					
November 7-8				11.0	
November 20-21		24.9	11.3	8.4	6.9
December 5-6			7.5	10.1	8.5
December 19-20			14.0		

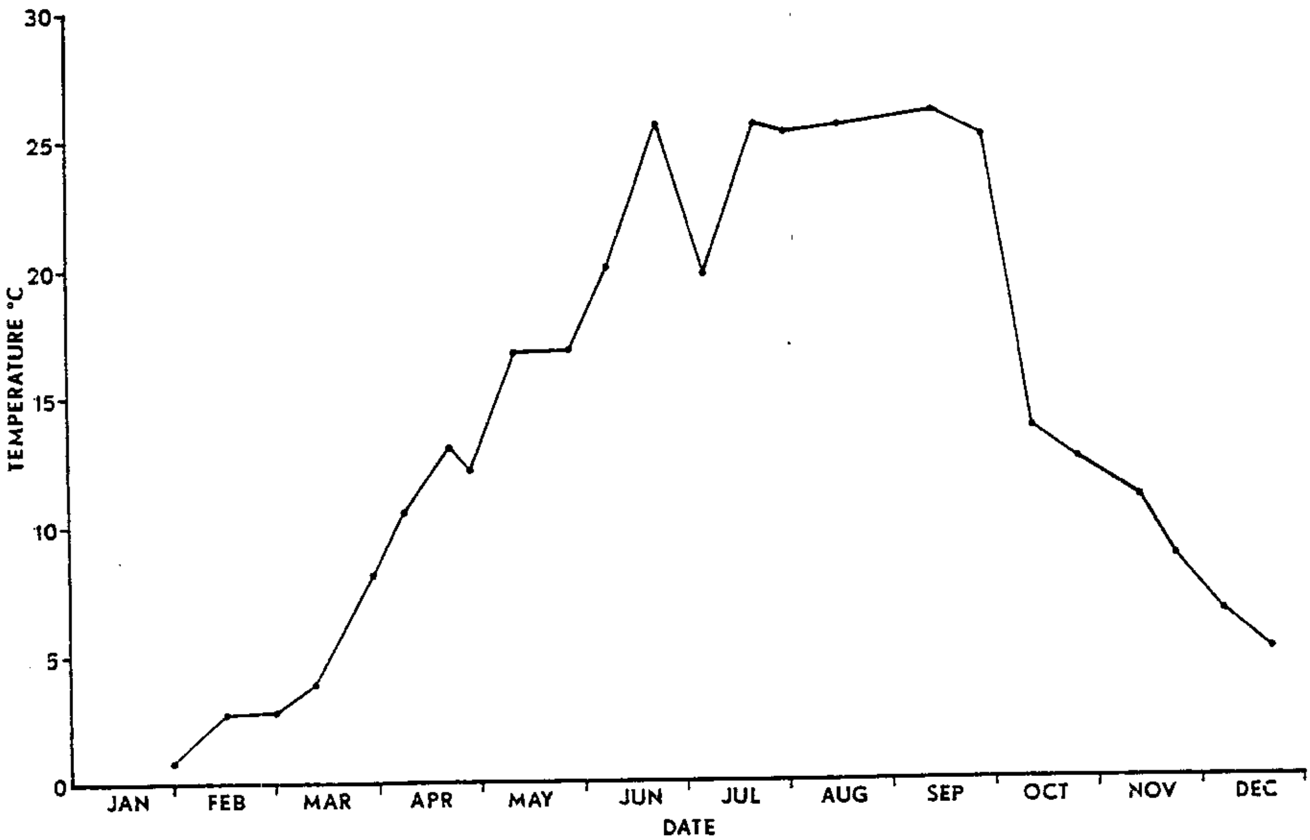
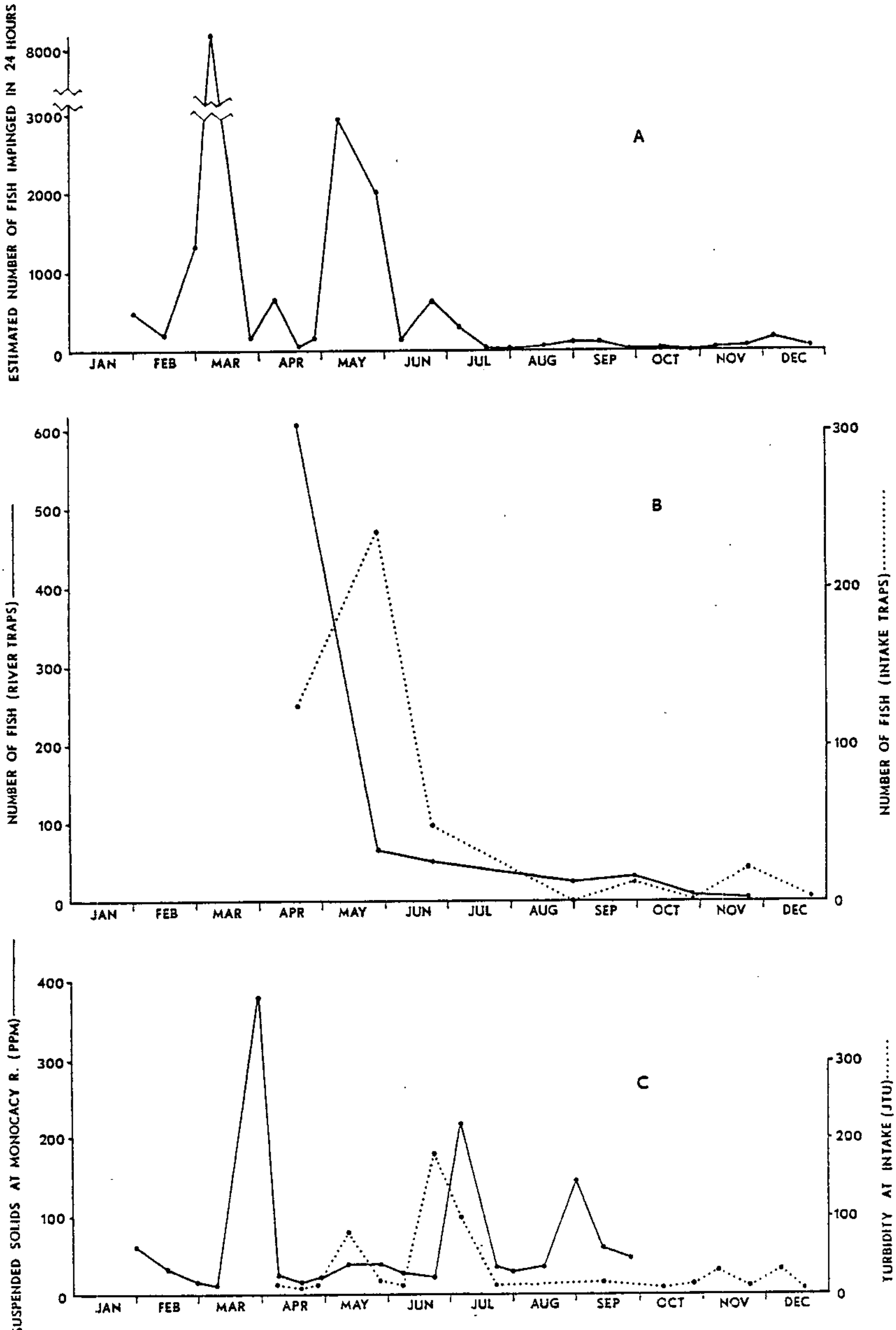


Figure V-A-7. Ambient river water temperature at the intake during impingement sampling periods of the 1978 impingement study at the Dickerson SES.

Figure V-A-8. Composite graph of (a) the estimated number of fish impinged per 24-h sampling period, (b) distribution of fish in the area of the Dickerson SES (dotted line is from immediately in front of intake structure, solid line is number of fish from river traps on Maryland half of the river), and (c) turbidity. The solid line is mg/l suspended sediments near Frederick, Md. (the day before the date of impingement sampling to allow for flow to the plant) and the dotted line is turbidity (JTU) measurements made at the intake.



A
ESTIMATED NUMBER OF FISH IMPINGED IN 24 HOURS
8000
3000
2000
1000
0
JAN FEB MAR APR MAY JUN JUL AUG SEP OCT NOV DEC
B
NUMBER OF FISH (RIVER TRAPS)
NUMBER OF FISH (INTAKE TRAPS)
600
500
400
300
200
100
0
300
200
100
0
JAN FEB MAR APR MAY JUN JUL AUG SEP OCT NOV DEC
C
SUSPENDED SOLIDS AT MONOCACY R. (PPM)
TURBIDITY AT INTAKE (JTU)
400
300
200
100
0
300
200
100
0
JAN FEB MAR APR MAY JUN JUL AUG SEP OCT NOV DEC

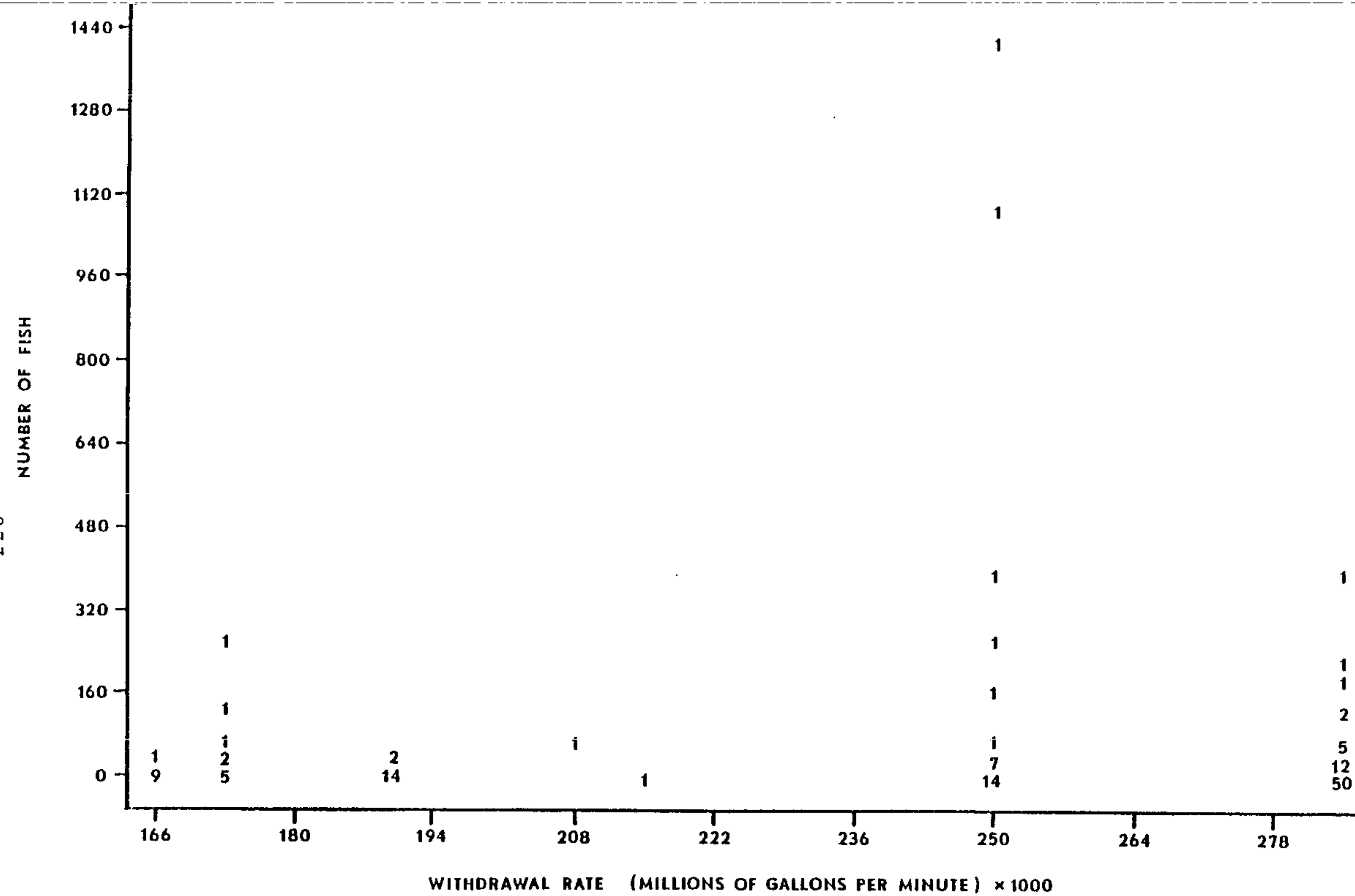


Figure V-A-9. The correlation between impingement levels and intake volume (millions of gallons of water per day) during the 1978 impingement study at the Dickerson SES. The numbers plotted represent the number of times the indicated quantities of fish (in increments of 32) were impinged at the shown volume of withdrawal in a 1-h sampling period.

Table V-A-11. Estimated monetary value of fish loss through impingement at the Dickerson SES during 1978.

Key to Groups:

LB - Largemouth Bass
SB - Smallmouth Bass
RB - Rock Bass
BH - Bullheads (all species)
CA - Carp
CC - Channel Catfish
FF - Forage Fish
CR - Crappie (Black and White)
AE - American Eel
MT - Madtoms
YP - Yellow Perch
SR - Suckers and Redhorse (all species)
SF - Sunfish (all species)

	LB	SB	RB	BH	CA	CC	FF	CR	AE	MT	YP	SR	SF
JAN*	17.92	44.80	0.00	4.48	4.96	408.35	10.03	44.00	29.36	0.00	0.00	23.00	262.88
FEB	35.84	89.60	0.00	8.96	9.91	816.70	18.31	58.24	0.00	0.00	0.00	45.99	120.96
MAR	0.00	0.00	0.00	0.00	7.83	92.02	150.98	46.99	0.00	0.00	0.00	23.49	135.09
APR	0.00	0.00	15.00	12.00	0.00	325.50	7.03	96.00	0.00	0.00	4.50	14.45	114.00
MAY	0.00	196.33	20.67	62.00	40.55	1,772.32	36.35	41.33	0.00	28.93	0.00	118.01	3,154.97
JUN	0.00	0.00	22.50	27.00	25.29	81.00	11.74	27.00	0.00	9.00	0.00	226.37	99.00
JUL	0.00	81.38	0.00	0.00	30.22	323.17	3.63	0.00	0.00	32.55	0.00	4.65	106.95
AUG	0.00	69.75	0.00	0.00	12.69	203.36	1.64	0.00	0.00	0.00	0.00	47.88	83.70
SEP	0.00	0.00	0.00	0.00	11.25	157.50	1.47	0.00	0.00	4.50	0.00	34.69	117.00
OCT	0.00	0.00	0.00	0.00	0.00	0.00	0.09	0.00	0.00	0.00	0.00	38.20	41.85
NOV	0.00	0.00	0.00	0.00	0.00	63.18	0.78	0.00	57.62	0.00	0.00	3.00	21.00
DEC	0.00	0.00	0.00	0.00	0.00	0.00	1.74	29.76	58.71	0.00	0.00	12.40	525.76
TOTAL:	53.76	481.86	58.17	114.44	142.71	4,243.10	243.79	343.32	145.69	74.98	4.50	592.13	4,783.16

Estimated total annual cost: $11,281.60

* Jan. costs are mean of Feb. and Dec.

Table V-A-12. Summary of fish distribution determined by the 1978 pre-impingement study at the Dickerson SES. Numbers under each river transect position represent the total fish caught at that position in all traps along the transect. The Virginia shore (VS) and the Maryland shore (MS) transects consisted of 10 traps each; all other transects (1-5) had 5 traps each (see Fig. V-A-2).

Date	River transect position						
	VS	5	4	3	2	1	MS
April 18-19	511	44	16	0	2	45	558
May 24-25	158	9	14	18	15	4	46
June 21-22	17	3	0	12	13	6	33
August 29-30	10	10	0	2	5	14	5
September 26-27	23	3	0	2	0	8	24
October 23-24	20	0	0	0	0	0	3
November 20-21	41	0	0	0	2	2	1
December 19-20	5	0	0	0	0	0	0
Total	785	69	30	34	40	155	670

In order to determine if the large community of *Notropis hudsonius* have moved out of the area, as suggested by the low numbers trapped, ten traps were placed 30 km downstream from the plant on November 19. After 2 h 50 *N. hudsonius* were collected. Only one was collected in the 63 traps in a 24-h period in the vicinity of the plant. Thus, it is evident that the traps still caught *N. hudsonius* effectively and that the large population of *N. hudsonius* that was present near the SES early in 1978 had dispersed.

Notropis hudsonius and *Notropis spilopterus* were the two most common fishes immediately in front of the intake structure. *N. spilopterus* was collected primarily in surface traps while *N. hudsonius* was collected primarily in bottom traps (Table V-A-13.

The longitudinal distribution study carried out in April indicated that *N. hudsonius* was much more common around the intake structure and upstream to the confluence of the Monocacy River than it was between the discharge and the lower end of Mason Island. The reverse was true for sunfishes and channel catfish (Fig. V-A-10). Temperature above the discharge was 12.8°C. The temperature of 20.7°C at the discharge declined linearly to the lower end of Mason Island where it was 17.8°C.

Mean current, depth and turbidity above the discharge were 0.10 m/sec, 1.0 m and 10.5 JTU's, respectively; below the discharge the corresponding values were 0.11 m/sec, 1.1 m and 9.8 JTU, respectively. These parameters were comparable above and below the discharge and were not related to the shifts in abundance previously described.

To compare the abundance of *Notropis hudsonius* in the vicinity of the plant, with its abundance in other portions of the river, a linear trap study was conducted on December 17-18; 1978. *Notropis hudsonius* had a spotty distribution throughout the study area (Table V-A-14). None were trapped in the immediate area of the plant during the linear trap study or the preimpingement sampling on the following day (December 19, 1978).

Discussion

The 1976-77 impingement study showed a potentially significant impact on young channel catfish *(Ictalurus punctatus)* and, to a greater extent, on spottail shiner (*Notropis hudsonius)*. The channel catfish is an important game fish and a Resident Important Species. Although the overall significance of the spottail shiner in the ecology of the Potomac River is not known, it, too, is a

Table V-A-13. Depth distribution of fish trapped in front of the intake structure of the Dickerson SES during the pre-impingement study, April-December 1978.

	April	May	June	Aug	Sept	Oct	Nov	Dec
	Notropis hudsonius (Spottail shiner)							
Surface	0	0	0	0	0	0	0	0
Mid-depth	4	0	0	0	0	0	0	0
Bottom	3	4	2	1	2	0	0	<1
	Notropis spilopterus (Spotfin shiner)							
Surface	15	34	6	0	0	0	2	0
Mid-depth	<1	0	0	0	0	0	0	0
Bottom	0	0	0	0	0	0	0	0
	Other species							
Surface	0	0	0	0	0	0	<1	0
Mid-depth	<1	0	0	0	0	0	0	0
Bottom	<1	<1	1	0	<1	<1	<1	<1

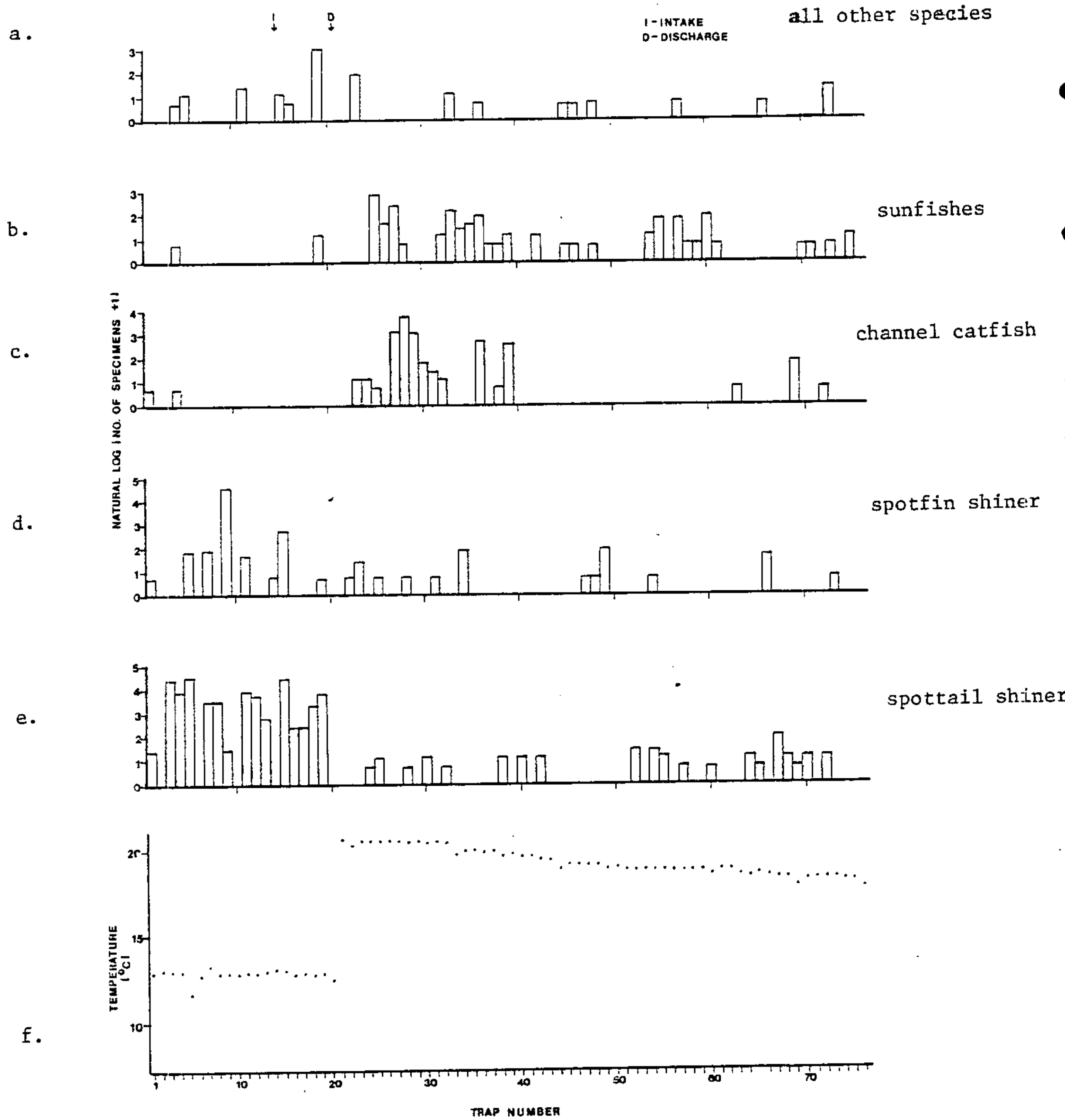


Figure V-A-10. Numbers of selected species and all other species combined collected in each trap during the April 1978 linear trap study. Temperature measurements at each trap are also presented.

Table V-A-14. Results of linear trap study conducted December 17-18, 1978 near the Dickerson SES. (Figure V-A-14 shows the positions of the traps).

Trap Location	Number of *Notropis hudsonius* collected
1	4
2	6
3	1
4	0
5	2
6	1
7	25
8	0
9	4
10	4
11	0
12	0
13	3
14	0
15	9
16	0
17	3
18	5
19	14
20	5

Resident Important Species as well as an important forage fish.

It was concluded that further investigations should be made on the impingement of fish by the Dickerson SES using a more rigorous sampling regime. Increased sampling frequency over a period of one year could provide more accurate information on seasonal fluctuations of impingement. Increased daily sampling would further characterize diel fluctuations. Furthermore, very little statistical confidence could be placed in seasonal or annual impingement estimates derived from the 1976-77 data. The increased sampling frequency during the 1978 study provided a greater degree of confidence in the estimates of impingement quantities.

We also suggested that in a future study impingement data be compared with an estimate of fish populations in this section of the river. This approach has been used by others (Edwards et al., 1976; Benda, 1976; Bernhard and Latvaitis, 1976) to better relate impingement levels to the distribution and relative abundance of fish in the river.

The 1978 study demonstrated, for the second time, high impingement of spottail shiners during March. Unlike the 1976-77 study however, the 1978 study demonstrated that high numbers of fish were impinged during May. During the rest of 1978 the quantity of fish impinged was relatively low.

Although the highest numbers of fish were impinged during March (Fig. V-A-5a), the greatest biomass (as total weight) was impinged during May (Table V-A-8). Seasonal summaries of numbers of fish impinged and total weight impinged (Fig. V-A-6a and Table V-A-9 respectively) indicate that winter impingement numbers were the greatest, but spring biomass impingement levels were the highest.

Mortality of impinged fish is assumed to be 100%. Several cursory studies were performed in which fish were removed from the screen backwash water trough and held in buckets of backwash water and observed. Within minutes all fish had died. Mortality could be due to one or several factors.

1) Fish could dessicate during the approximately 20 min excursion time on the rotating screens, the time from their removal from the water to their being washed off the screens.

2) Fish could be shocked (thermal, pH, alkalinity, DO) when washed off the screens with water piped from the plant (as opposed to raw river water).

3) Fish could be killed by the drop from the top of the intake structure to the trough by which they are transported to the discharge canal.

In accordance with paragraph F.(1) of the State of Maryland Water Resources Administration's Regulation 08.05.04, the monetary value of fish loss due to impingement was determined. COMAR 08.02.09.01 presents the values of all fish, according to their length and weight. The value of the total fish loss for one year was estimated to be $11,281.60. Mitigation measures are required as stated in paragraph F. of the State of Maryland Water Resources Administration's Regulation 08.05.04.

The 1978 impingement and pre-impingement studies, supplemented with data on chemical-physical conditions and plant operation, have provided some information on factors controlling the level of fish impingement by the SES.

Diel Cycle of Impingement

Collections during the 1978 study were made over a 24-h period to determine the diel nature of impingement. The 1976-77 study demonstrated a tremendous peak at dusk; however, there was only one sampling, so no conclusions could be drawn. Table V-A-7 shows that there was no large, consistent dawn or dusk effect during the 1978 study. For this reason extra dawn and dusk sampling was not continued. What was apparent, however, was the increased number of fish impinged during the hours of darkness. In only 3 collections out of 25 did the daylight sample size exceed the night-time sample size.

Pre-Impingement Data

It is not surprising that the most significant factor influencing the quantity of fish impinged appears to be the distribution of fish in the vicinity of the SES. A major trend may be seen when the number of fish impinged and the concurrent number of fish trapped in the river are compared (Figs. V-A-8a and b). Populations of fish (primarily spottail shiners) were high in the vicinity of the plant during the times when impinged numbers were highest. Although ice prevented the placing of traps in the river before mid-April, it is obvious that there were large numbers of spottail shiners present in the area because of the large numbers impinged in March. Throughout the rest of the year (July through December) impinged numbers remained quite low, coinciding with a decrease in the number of fish collected in the river.

Additional studies provided further insight into why *Notropis hudsonius* was more vulnerable to entrainment than other species. Intake traps indicated that *N. hudsonius* was found near the bottom where water is drawn into the plant (Table V-A-13). *N. spilopterus*, often common in front of the intake, was found in surface waters above the exposed portion of the intake screens. A longitudinal study carried out in April indicated that in the spring (season of sporadically high impingement) *N. hudsonius* was much more common around the intake structure than other species such as sunfish and channel catfish which were common below the discharge (Fig. V-A-10). A longitudinal study carried out in December after two seasons of low impingement indicated that *N. hudsonius* had a spotty distribution and was not found in large numbers in the region around the SES at that time.

Note that sometimes *N. hudsonius* and *N. spilopterus* were trapped in front of the intake structure during periods when almost no impingement occurred (e.g., April 18-19, 1978, Fig. V-A-4a and b and Table V-A-7).

Turbidity

Comparing turbidity with the numbers of fish impinged (Figs. V-A-8a and c) results in some contradiction. Although the high impingement level observed in March does not positively correlate with high turbidity, note that in some cases fluctuations of turbidity and impingement correspond. The correlations occur until approximately the middle of the year; during those months relatively large numbers of fish were being trapped in the river (Fig. V-A-8b). It might be assumed, therefore, that the inability of fish to see the revolving screens could be the mechanism by which turbidity influences impingement. Too few data are available, however, to draw strong conclusions about the influence of turbidity on impingement.

Temperature

Temperature is directly related to the swimming speed of fish and, therefore, to their capability to escape from the intake. However, neither the 1976-77 study nor the 1978 study shows a clear correlation between temperature and impingement rate. It is possible that the distribution of fish in the river changes throughout the uear as a function of temperature. If this occurred, it could quite possibly mask, or confound, the effects of temperature on swimming speed.

Intake Volume

No clear-cut relationship can be seen between numbers of fish impinged and the volume of water being drawn into the intake structure. Figure V-A-9 shows that the highest impingement rates observed occurred at times other than the periods of highest withdrawal rates. Impingement rate is theoretically correlated with intake velocity. However, due to variations in the size of the fish community in the river the correlation is not evident.

Summary and Conclusions

The 1976-77 study indicated that large numbers of spottail shiners (*Notropis hudsonius*) were impinged in March. A second, more rigorous study entailing bimonthly sampling, 24-h sampling periods, supplemental data collection on chemical-physical variables, plant operation and fish distribution within the river in the area of the SES was conducted in 1978. The findings of the 1978 studies are:

1) Impingement was very high during March with spotfin shiners making up 99% of the impinged fish (the same finding as in 1977).

2) A second high peak of impingement occurred in May with spottail shiners, spotfin shiners, sunfish and channel catfish being impinged in large numbers.

3) Most fish are impinged at night.

4) Pre-impingement data show that fish are primarily distributed along the shore-zones of the river.

5) Impingement rate appears to be correlated with the numbers of fish in the vicinity of the intake structure.

6) Chemical-physical variables do not appear to be correlated with impingement levels.

7) The monetary value of the fish destroyed by impingement during 1978 was $11,281.60.

Impingement levels are low for most of the year; the only exception being the periods of March and May when as many as 8,102 spottail shiners were impinged in 24 h. Since studies were not conducted to determine any impact of impingement mortality on the fish community, such an assessment is not presently possible.

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V-B. FISH EGG AND LARVAE ENTRAINMENT

Introduction

From April 23 to August 20, 1978, a study of fish egg and larvae entrainment was carried out to assess potential impacts of the Dickerson Steam Electric Station once-through cooling system. It was expected that a portion of drifting eggs and larvae would be drawn through the plant in coolant water and that some would be killed or injured. The primary objective was to measure the magnitude of drift in this area of the Potomac and entrainment rates at Dickerson and to compare and evaluate these rates.

In a previous study (ANSP, 1974), it was determined that many fish species in the Dickerson area spawn extensively in tributary streams or in backwater areas where the eggs and larvae would not be affected by the plant. Eggs of other species that spawn in the area are firmly attached and relatively few drift. Unpublished data from a study of aquatic insect drift carried out in 1976 (ANSP, 1978) suggested low levels of larval fish entrainment. The decision to do this larger study was based on the need for data from an entire spawning season, and for data representing a variety of environmental conditions, i.e., varying flow, temperature and turbidity. In addition, such a study was deemed necessary for an adequate 316 b demonstration since no previous studies were designed specifically to measure entrainment of fish eggs and larvae by the Dickerson SES.

Methods and Procedures

Drift was measured along a transect just upstream from the intake structure. Densities were determined for near-shore zones on both sides of the river as well as the main channel. Entrainment was estimated from collections made in the discharge canal. It was not possible to devise a method to collect representative samples from the intake since it is submerged and subject to unpredictable deep-water currents.

Two supplemental studies were designed to help evaluate entrainment data. A mortality study assessed larval survival during a 24-hour period after passage through the plant. In another study, a comparison was made of abundance of larvae in shoreline nursery areas above and below the plant to determine if possible entrainment mortalities were associated with decreased population size below the discharge. This study also helped indicate the size of populations found at the shoreline where drift was expected to be minimal because currents there are gentle compared with those offshore.

Drift and Entrainment Study

Drift samples collected in the river comprised four subsamples from each near-shore zone and four from the channel zone. Subsample collecting points differed with each sample and were selected with the aid of a random number table from the locations shown in Figure V.B-1. Eggs and larvae were collected with 0.5-m plankton nets with 500-µ mesh width. They were mounted on stainless steel cones (which decelerated water passing through the nets) such that the effective diameter of the net was 0.43 m (Fig. V.B-2). The line from which the sampler was suspended was attached behind the mouth of the cone, i.e., the net was not preceded by a bridle. Bridleless nets appear to help reduce avoidance of the net by larvae by reducing hydrostatic pressure cues (Bowles and Merriner, 1978). Previous field tests using dye indicated that the samplers adequately measured sample volume and retained specimens (ANSP, 1978). Flow through the nets was measured with model 2030 General Oceanics flow meters. Densities of eggs and larvae were estimated by dividing the number collected by the volume of water that flowed through the nets. Nets were lowered from an anchored boat for 6 min at each subsample location on the river. Nets were held at the bottom, mid-depth and surface for 2 min each. When the depth was less than 1.5 m, nets were held for 3 min at the surface and 3 min on the bottom. Water in the discharge canal was considered mixed across the width of the canal.

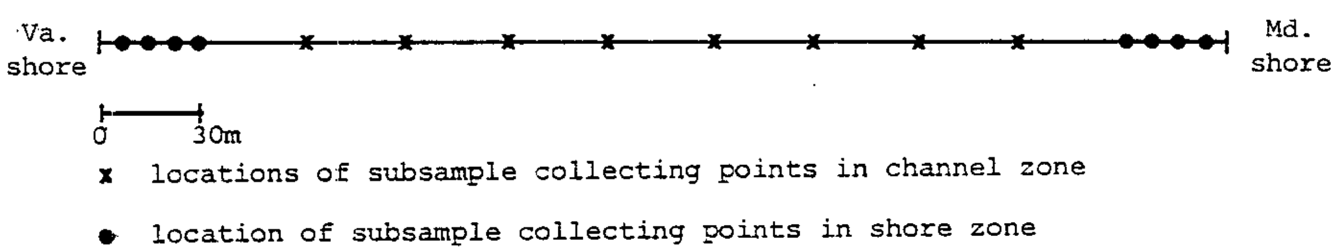


Figure V.B-1. Diagram of transect showing sampling locations.

Initially, subsamples from the channel zone were pooled as were those from the combined shore zones. On May 23 and thereafter, subsamples from the Maryland and Virginia sides were preserved separately. Samples were collected every 33 hr from April 23 to July 6 and every 66 hr until the conclusion of the study on August 20, when spawning was less intense. During the first period, five samples, evenly spaced through the diel cycles, were collected each week; in the second period, five such samples were collected in two weeks.

Entrainment samples were collected in the discharge canal.

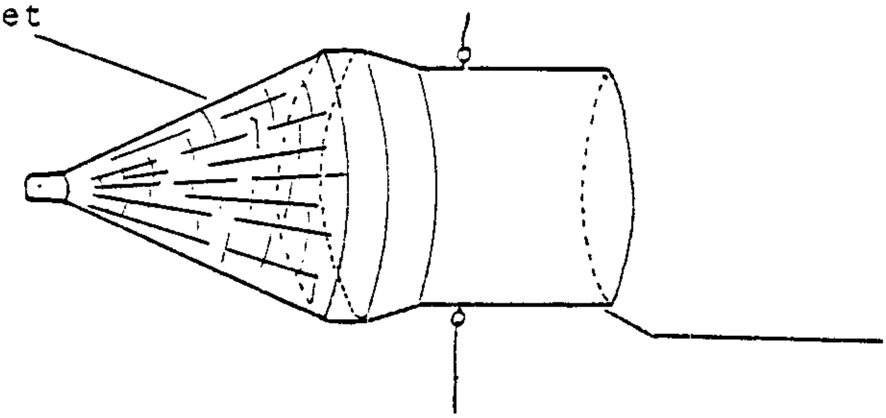


Figure V-B-2. Plankton net used to collect fish eggs and larvae in the vicinity of the Dickerson SES in 1978.

These collections were made immediately after drift collections were completed, i.e. every 33 hours. Before May 14, 1978, three subsamples were spaced across the canal. However, rapid turbulent currents made it impractical to maintain the boat in these three positions. Since the discharge was considered laterally mixed, one collection of 18 min was substituted for three 6-min collections. The net was held for an equal length of time at the bottom, mid-depth and surface.

The physical parameters light intensity, turbidity, water temperature and depth were measured with each collection at each subsample location. Turbidity was measured with a Hach 2100 turbidimeter, and temperature was measured with a YSI Model 44 TD thermistor. Light intensity was measured with a Sekonic L-398 light meter. Sample values were represented as a mean of subsample values.

Drift rate was estimated by multiplying egg and larval density (numbers/unit volume) by river flow. River flow data was obtained from United States Geological Survey records. The flow at the plant was taken to be the sum of the flow of the Potomac River at Point-of Rocks plus that of the Monocacy River at Jug Bridge. Drift estimates were made separately for channel and near-shore zones. Drift during a given sampling was estimated as follows:

$$\text{Estimated drift rate in channel zone} = \frac{(9/11(\text{river flow})) \times (\text{number of specimens captured in that channel zone sample})}{\text{Volume of water strained for sample}}$$

$$\text{Estimated drift rate in near-shore zone} = \frac{(2/11(\text{river flow})) \times (\text{number of specimens captured in that near-shore zone sample})}{\text{Volume of water strained for sample}}$$

Note that flow in each zone was estimated by multiplying river flow by 9/11 for the channel zone and 2/11 for near-shore zone. These fractions were used because the channel zone comprised 9/11 of the river width (Fig. V.B-1) and therefore a similar proportion of the cross-sectional area because depth was relatively uniform across the river. Entrainment estimates were calculated similarly:

$$\text{Estimated entrainment rate} = \frac{(\text{Plant pumping rate}) \times (\text{number of specimens captured in discharge sample})}{\text{Volume of water strained for sample}}$$

Total drift and entrainment for the sample season were estimated by multiplying the mean of sample rates by the duration of the sampling period (April 23 to August 20). Flow through the plant was obtained from plant records. Entrainment was expressed as a percent of drift: (entrainment/drift) x 100.

Data were sometimes represented graphically following a natural logarithmic transformation: Ln (Drift + 1) or Ln (Density + 1). Such data were also used to calculate a lateral distribution coefficient: sum of density values for near-shore zone divided by sum of density values for near-shore zone plus density values for channel zone. Sums were made across all samples after logarithmic transformation. In a similar way a diel coefficient of drift variation was calculated from transformed data: mean nighttime drift value divided by mean nighttime drift value plus mean daytime drift value.

Larvae were identified using several guides: U.S. Fish and Wildlife Service (1978), Lippson and Moran (1974), Loos et al., (in press) and Hogue, Wallus and Key (1976). In addition, Barbara Lathrope of Ichthyological Associates, Inc., Etters, Pennsylvania, identified representative *Ambloplites rupestris* (rock bass) larvae and Robert Wallus of the Tennessee Valley Authority, Norris, Tennessee, identified *Etheostoma blennioides* (greenside darter) representatives and suggested very similar specimens may have been *Percina peltata* (shield darter). Many specimens were identified to species, but it was not possible to differentiate the genera *Hypentelium*, *Catostomus*, and *Moxostoma* because these are morphologically similar in early development. These taxa were combined under the family Catostomidae. It was also not possible to differentiate between *Etheostoma blennioides* and *Percina peltata* nor between *Notropis spilopterus* (spotfin shiner) and *Pimephales notatus* (bluntnose minnow) in the earliest developmental phase. Specimens were classified by developmental phase as described by Snyder (1976).

Entrainment Mortality Study

Samples for mortality studies were collected with plankton nets mounted on cones described earlier (Fig. V.B-2). Nets with 330-μ mesh width were substituted for the standard mesh width and a 19-l plastic bottle was substituted for the standard collecting bucket attached to the cod end of the net. Also a perforated clear plastic sheet was placed across the wide end of the cone at the mouth of the net. These modifications reduced injuries to larvae during sampling: the finer mesh prevented larvae entanglement in the net; the larger collecting bucket reduced water velocity and provided a larger volume of water in the bucket. The perforated sheet (250 openings, 1 cm in diameter) reduced the open area at the net mouth by one tenth (from 0.20 m^2 to 0.020 m^2), thus slowing the current flowing through the net so that larvae would not be pressed against the edges. Initial trials of this modified net indicated that in the discharge the flow was appropriately reduced while sample size remained adequate. However, the river current was slower than in the discharge and the modifications so reduced flow through the net that the volume sampled was too small. Thus use of this net precluded collection of comparable control samples. Inspite of this, an attempt was made to collect a control sample during the last mortality study in the Maryland near-shore zone. Mortalities noted in this collection may have resulted from handling of the larvae and/or from natural mortality.

No attempt was made to evaluate effects of chlorine on larval mortality. The sampling period was such that the chlorination cycle should not have biased results. During these studies the plant injected chlorine four times a day, starting at 0730, 1330, 1930 and 0130 hours. The cycle comprised a 5-min rinse and a 20-min injection period. Units were injected one at a time in numerical order with 20.4 kg per unit per day. Nets were set between 2200 hours and 2300 hours. The sample duration was 6 hr and included one chlorine injection cycle.

Three mortality samples were collected on each of the nights of June 10 and 11, June 20 and 21 and June 30 to July 3. Because larvae became scarce, the last sample was a composite of three collections (6-hr collections on three consecutive nights) to obtain a more adequate number of specimens. Mortality studies were terminated after the third study because of difficulties in obtaining adequate numbers of specimens.

Shoreline Survey

A single short-term shoreline study was made from August 21 to 23. A similar number of hauls were carried out above and below the discharge on each day so there would be no temporal bias.

Shallow water depth and slow current at the shoreline precluded sampling with a plankton net. Instead a 1.8-m seine with 1-mm square mesh was used to collect larvae and small juveniles. It was placed 1.8 m from shore and pulled directly toward the bank. One haul covered 3.3 m^2. Forty-four seine hauls, spaced at 90-m intervals, were made along the Maryland shore from the Monocacy River to a point just upstream of the upper end of Mason Island; 21 of these hauls were made above the discharge. An additional 28 seine hauls were made in backwater and cove areas; half of these were made above the discharge. Water temperature, depth and qualitative observations of bottom type and current were noted with each seine haul.

As the bottom of the seine dragged over the bottom, detritus and fish were scooped into the net. Young fish were picked from the detritus in the laboratory, then counted by developmental and taxonomic category as described earlier. Specimens up to 25 mm TL (total length) were included.

Results

Drift and Entrainment Studies

Twenty taxonomic groups were identified (Table V.B-1); eighteen were collected from drift samples and 18 from entrainment samples. Species not common to both lists were represented by fewer than 10 specimens.

Drift and entrainment species were small (Table V.B-2), but larger sunfishes, suckers and catfishes were collected later in the year. Catfish, in particular, were large and robust (Fig. V.B-3; Table V.B-2); therefore, their relative contribution to drift biomass, compared with other species, was greater than indicated by their numbers.

In three cursory samples taken during the 10-day period before April 23, only two eggs and one larva were collected, an indication that there was little drift or entrainment at the time. Sampling was initiated at the beginning of the spawning season for most species (Loos, et al., in press; U.S. Fish and Wildlife Service, 1978). Also near the end of the study, drift and entrainment had declined to low levels when spawning for most species had concluded. Therefore, the study encompassed that period during which most drift and entrainment occurred. There were two large peaks in numbers of drifting eggs and larvae (Fig. V.B-4): one occurred in early May (before a flood) and consisted largely of spottail shiners (Fig. V.B-5b); the other occurred after the flood, which was probably responsible for the interruption in spawning. The second peak resulted from the simultaneous spawning of many species and occurred during a period of rapidly rising temperature in late May and early June (Figs. V.B-4-9). Concurrent with these peaks were increased rates of entrainment. The maximum entrainment occurred in the seventh week when the average rate was 19 individuals per sec and when drift was also high (Fig. V.B-4). In the first and last weeks the mean rate was less than 0.4 individuals per sec.

Estimates of numbers of eggs, larvae and juveniles drifting

Table V.B-1. Numbers of fish eggs, larvae and juveniles identified from drift and entrainment samples collected in the vicinity of the Dickerson SES in 1978.

	Type of Sample	
	Drift	Entrainment
1. *Cyprinus carpio* (Carp)		
egg	26	60
protolarva	595	221
juvenile	0	2
2. *Notropis amoenus* (Comely Shiner)		
egg	0	1
3. *Notropis cornutus* (Common Shiner)		
protolarva	14	9
mesolarva	1	0
metalarva	1	1
juvenile	1	0
4. *Notropis hudsonius* (Spottail Shiner)		
egg	709	61
protolarva	1055	785
mesolarva	2	2
metalarva	1	4
5. *Notropis rubellus* (Rosyface Shiner)		
protolarva	1	4
6. *Notropis spilopterus* (Spotfin Shiner)		
egg	14	35
mesolarva	0	3
7. *Pimephales notatus* (Bluntnose Minnow)		
mesolarva	4	3
juvenile	0	2
N. spilopterus and/or *P. notatus*		
protolarva	709	335
8. *Rhinichthys atratulus* (Blacknose Dace)		
protolarva	2	3
mesolarva	0	2
9. *Rhinichthys cataractae* (Longnose Dace)		
protolarva	0	6
mesolarva	0	1
10. *Catostomidae* -- any or all of the following:		
Hypentelium nigricans (Hog Sucker)		
Catostomus commersoni (White Sucker)		
Moxostoma erythurum (Golden Redhorse)		
Moxostoma macrolepidotum (Shorthead Redhorse)		
egg	8	4
protolarva	3	0
mesolarva	87	135
metalarva	2	6
juvenile	1	1

Table V.B-1 (continued). Numbers of fish eggs, larvae and juveniles identified from drift and entrainment samples collected in the vicinity of the Dickerson SES in 1978.

	Drift	Entrainment
11. *Erimyzon oblongus* (Creek Chubsucker)		
protolarva	1	0
12. *Ictalurus natalis* (Yellow Bullhead)		
metalarva	21	14
juvenile	1	0
13. *Ictalurus punctatus* (Channel Catfish)		
mesolarva	1	9
metalarva	229	62
juvenile	9	3
14. *Noturus insignis* (Margined Madtom)		
metalarva	2	6
juvenile	2	1
Ictalurid sp (s) undetermined catfish		
egg	0	2
15. *Ambloplites rupestris* (Rockbass)		
metalarva	1	1
16. *Lepomis auritus* (Redbreast Sunfish)		
protolarva	2	1
mesolarva	6	0
17. *Lepomis* spp (any *Lepomis* sp. except *L. auritus*		
protolarva	6	4
mesolarva	3	0
metalarva	4	0
juvenile	1	0
18. *Pomoxis* spp (Crappie)		
protolarva	1	0
19. *Etheostoma olmstedi* (Tessellated Darter)		
protolarva	377	318
metalarva	0	1
juvenile	0	2
20. *Etheostoma blennioides* (Greenside Darter) and possible *Percina peltata* (Shield Darter)		
egg	8	6
protolarva	55	116
mesolarva	0	1
Other undetermined specimens		
egg	11	12
protolarva	7	11
mesolarva	0	2
metalarva	0	2
juvenile	1	0
undetermined larval phase	1	1

Table V.B-2. Mean total length and size range of fish larvae and small juveniles collected in drift and entrainment samples at the Dickerson SES in 1978.

	Mean of sample statistics[1] (mm)		
	Mean	Largest	Smallest
Carp *(C. carpio)*	5.9	6.7	5.2
Spottail Shiner *(N. hudsonius)*	5.5	6.4	4.7
Common Shiner *(N. cornutus)*	7.8	8.7	7.6
Rosyface Shiner *(N. rubellus)*	7.1	7.3	7.0
Spotfin Shiner/Bluntnose Minnow *(N. spilopterus/P. notatus)*	5.5	6.7	4.7
Blacknose Dace *(R. atratulus)*	7.6	7.8	7.4
Longnose Dace *(R. cataractae)*	8.7	8.5	8.4
Sucker *(Catostomidae)*	14.9	15.7	14.4
Yellow Bullhead *(I. natalis)*	15.2	16.2	14.5
Channel Catfish *(I. punctatus)*	15.8	18.1	14.2
Margined Madtom *(N. insignis)*	17.2	19.1	15.8
Redbreast Sunfish *(L. auritus)*	7.5	7.7	7.4
Other Sunfish *(Lepomis* spp.*)*	7.9	8.6	7.3
Tessellated Darter *(E. olmstedi)*	5.5	6.2	5.1
Greenside Darter *(E. blennoides)*	7.3	8.0	6.9

[1] Σ sample means/number of samples; Σ Max. TL by sample/ number of samples; etc.

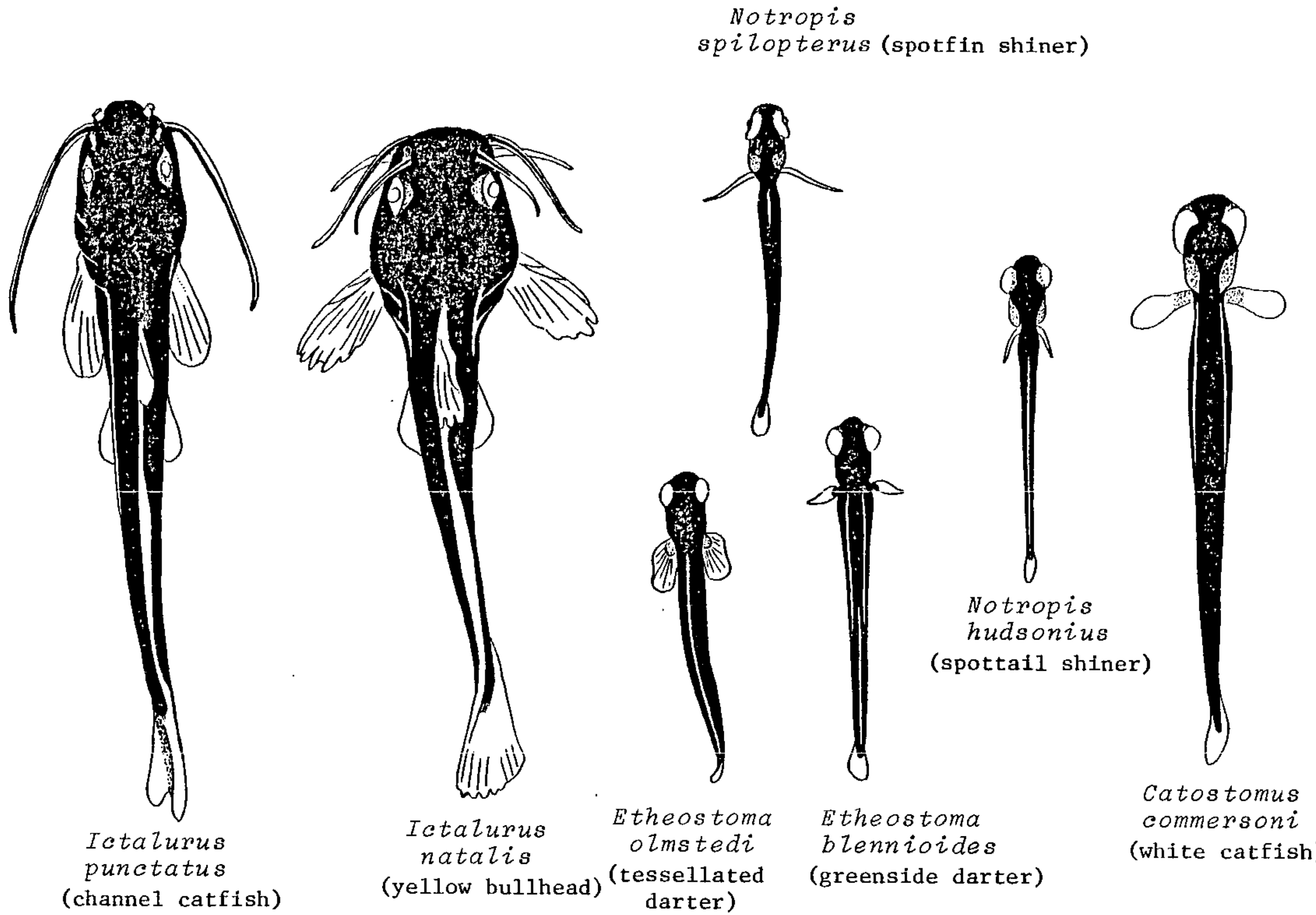


Figure V.B-3. Dorsal view of typical representatives of three families from drift samples collected in the vicinity of the Dickerson SES in 1978.

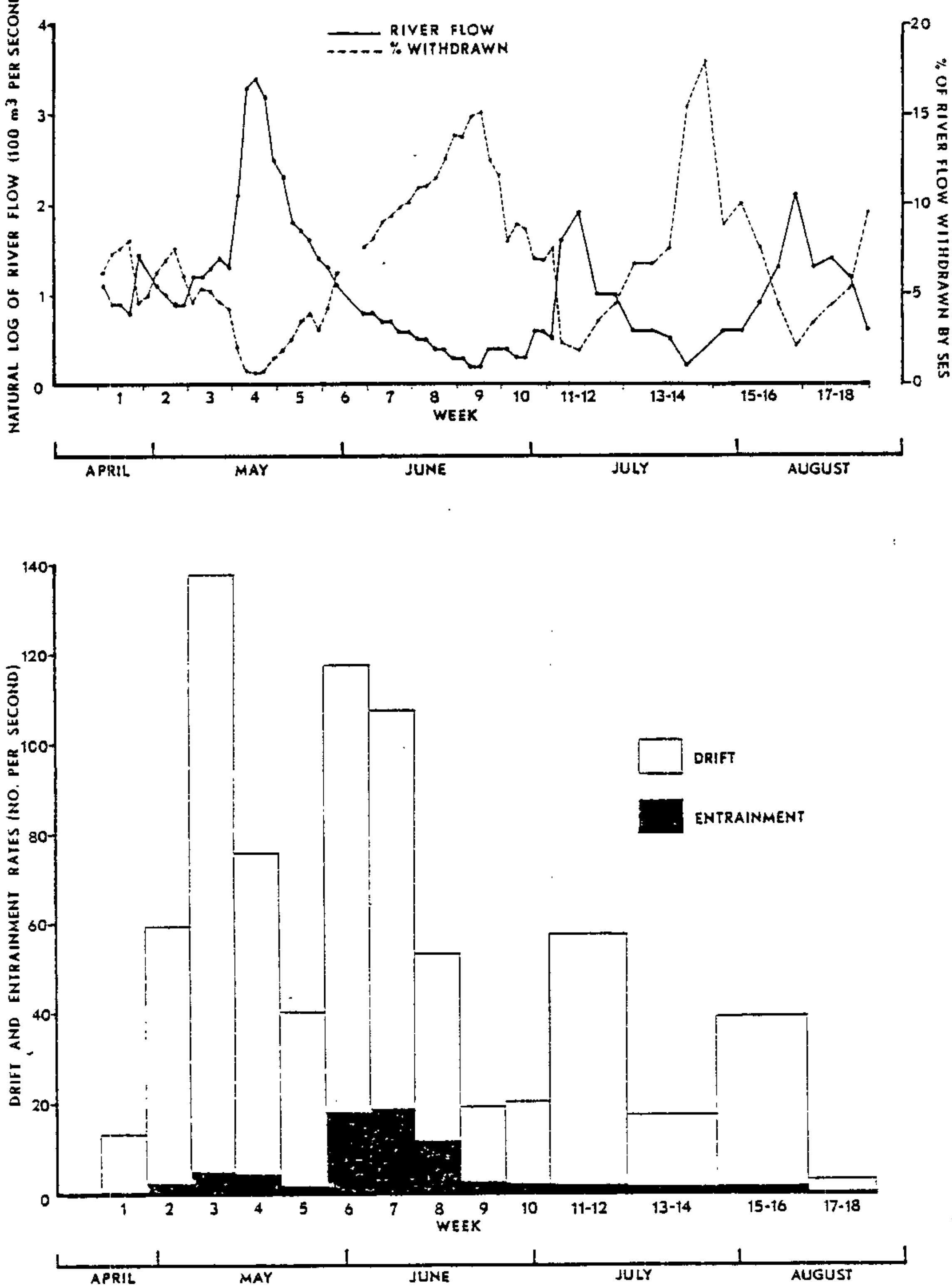
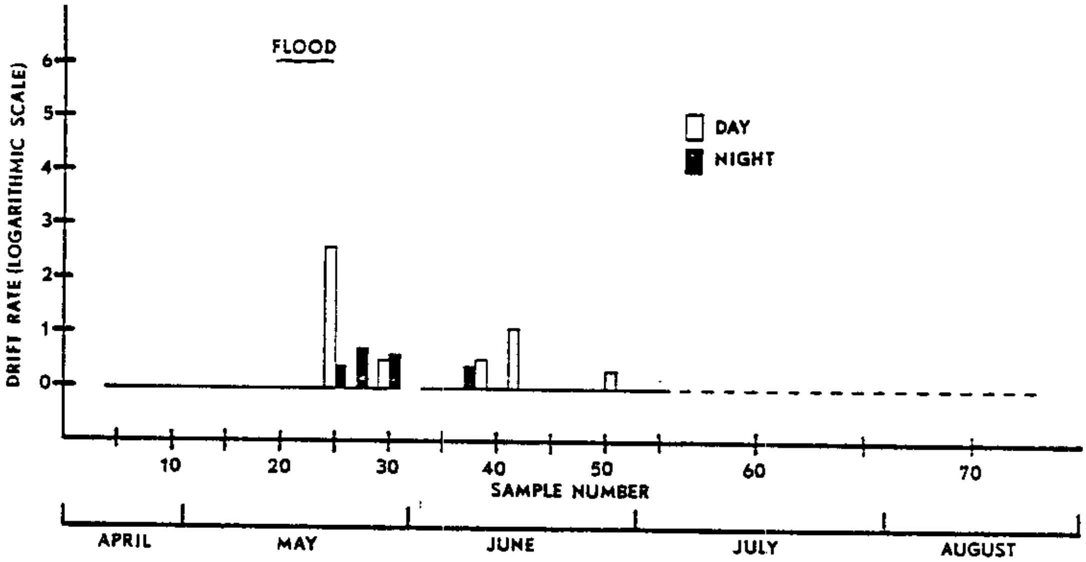


Figure V.B-4. Comparison of river flow and plant withdrawal of water with estimated drift and entrainment rates (numbers per second) at the Dickerson SES in 1978.

A. Carp (*C. carpio*)



B. Spottail shiner (*N. hudsonius*)

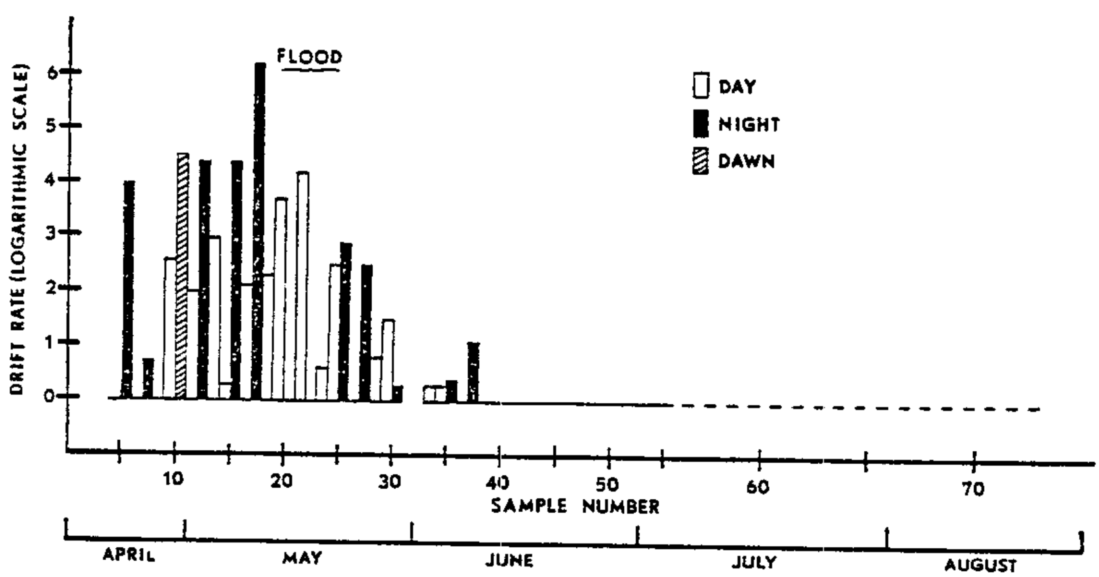
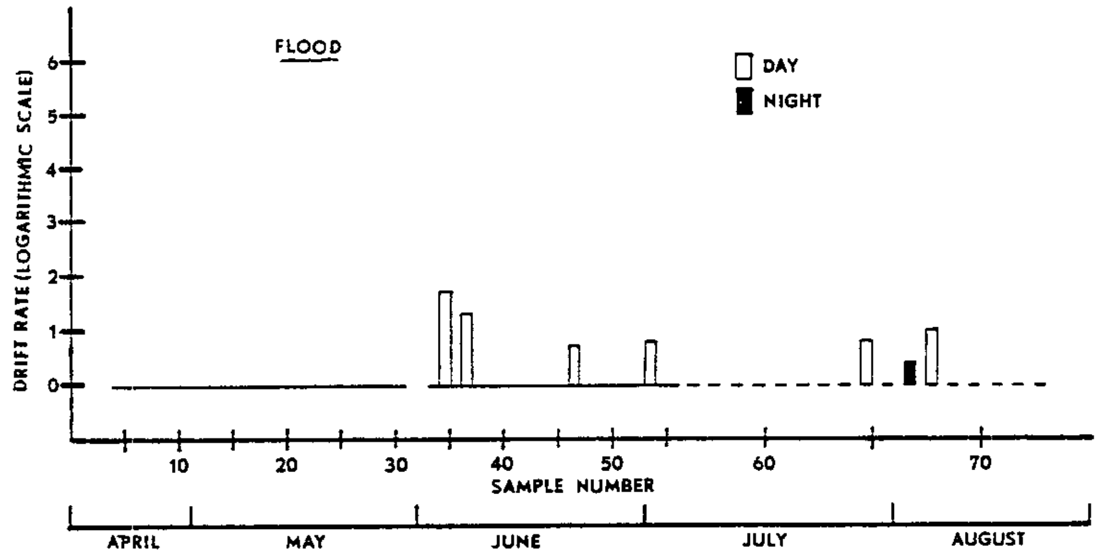


Figure V.B-5. Drift rate of fish eggs collected in the vicinity of the Dickerson SES in 1978 (logarithmically transformed data). Species were included if they were represented by at least 10 specimens in drift samples.

C. Spotfin shiner (*N. spilopterus*)



D. All species

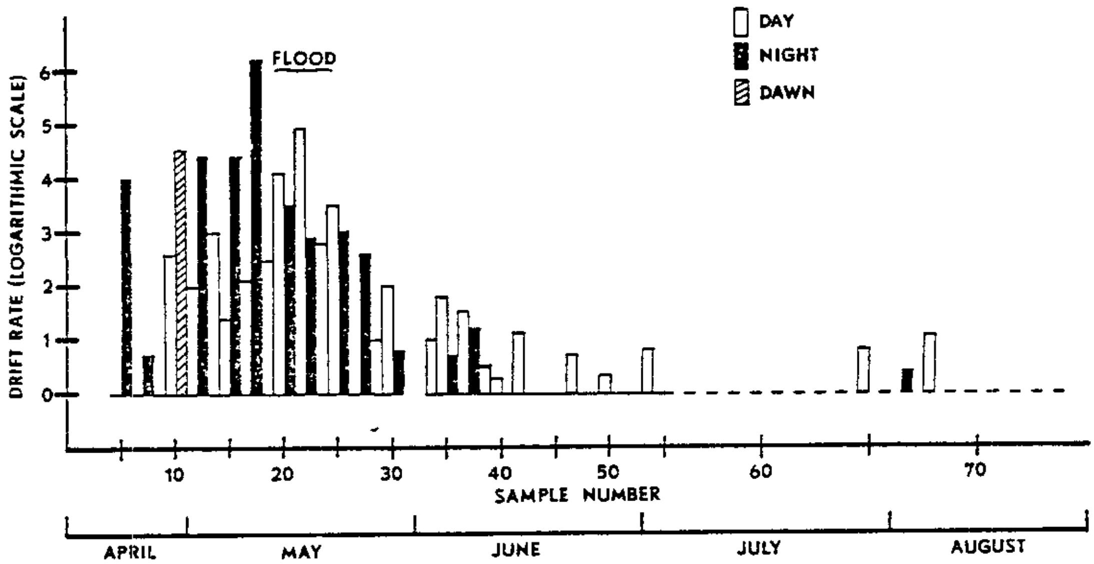


Figure V.B-5 (continued). Drift rate of fish eggs collected in the vicinity of the Dickerson SES in 1978 (logarithmically transformed data). Species were included if they were represented by at least 10 specimens in drift samples.

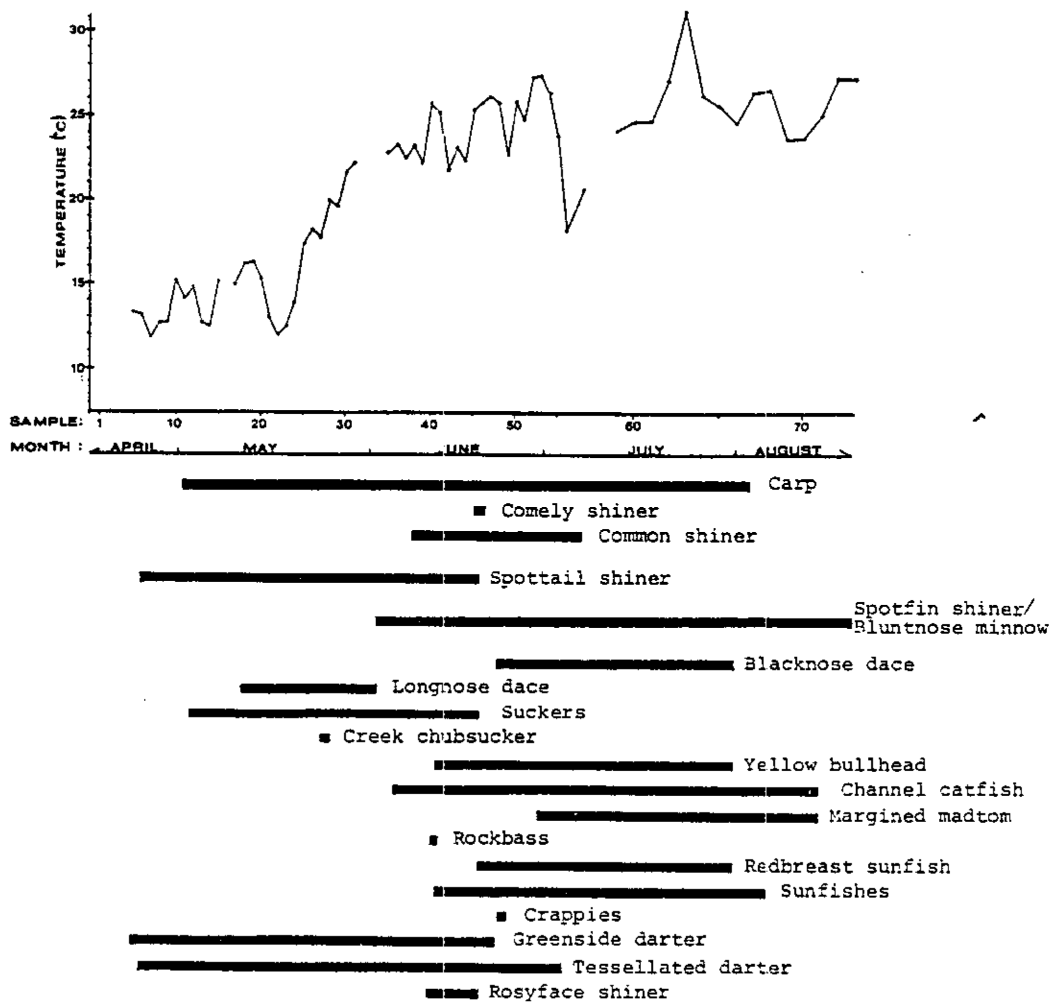
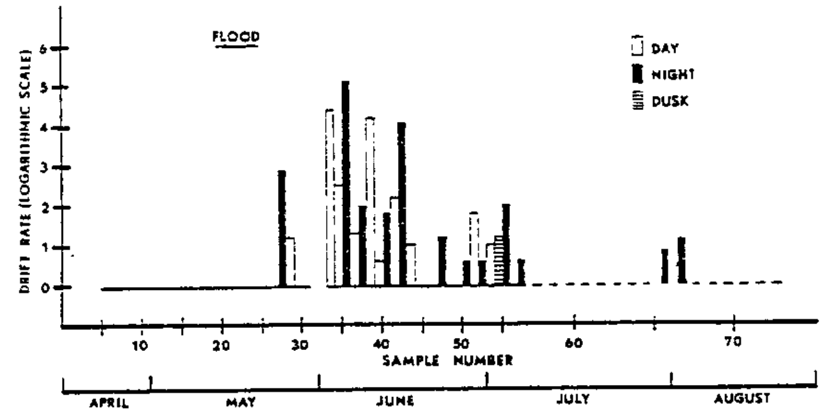
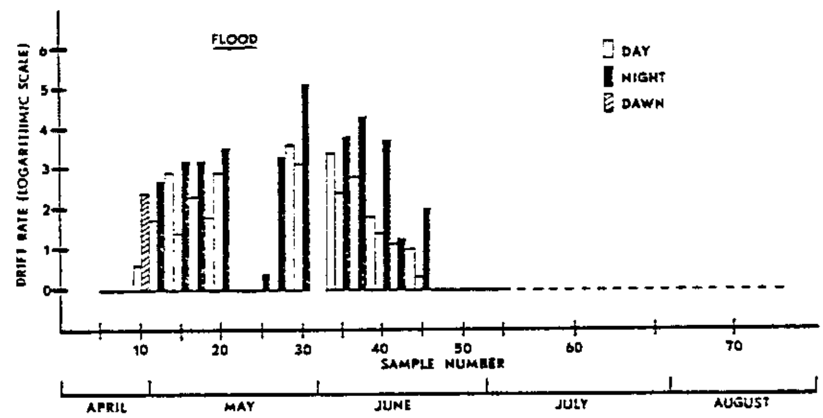


Figure V.B-6. Comparison of water temperature and temporal occurrence of fish eggs and larvae collected in the vicinity of the Dickerson SES in 1978.

A. Carp (*C. carpio*)



B. Spottail shiner (*N. hudsonius*)



C. Spotfin shiner (*N. spilopterus*)

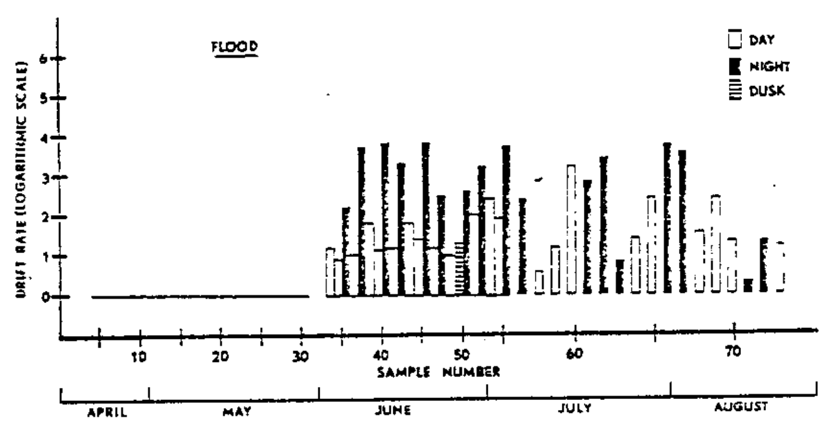
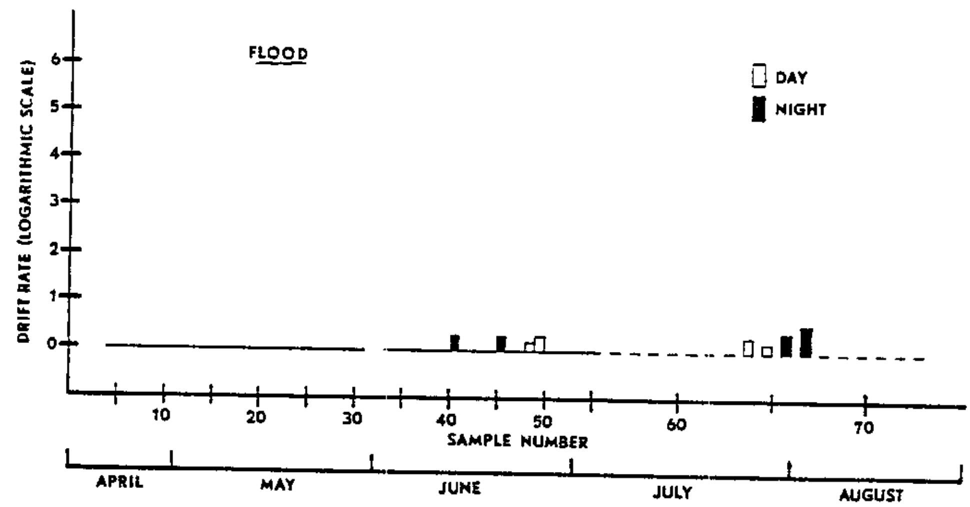


Figure V.B-7. Drift rate of protolarval fish collected in the vicinity of the Dickerson SES in 1978 (logarithmically transformed data). All species except the common shiner (*Notropis cornutus*) were included if represented by at least 10 specimens in drift samples. Sunfishes, though poorly represented, were also included because of the recreational value of the adults.

D. Sunfishes (*Lepomis* spp.)



E. Greenside darters (*E. blennioides*)

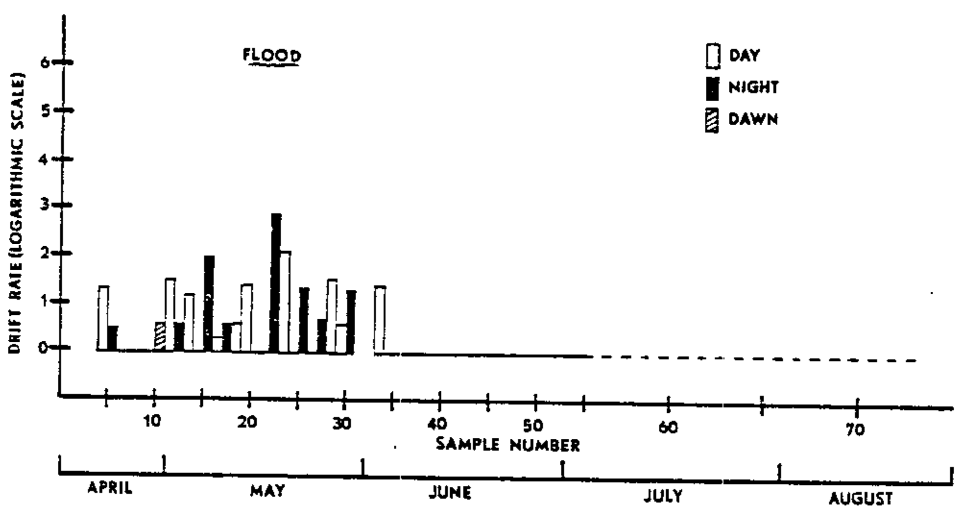
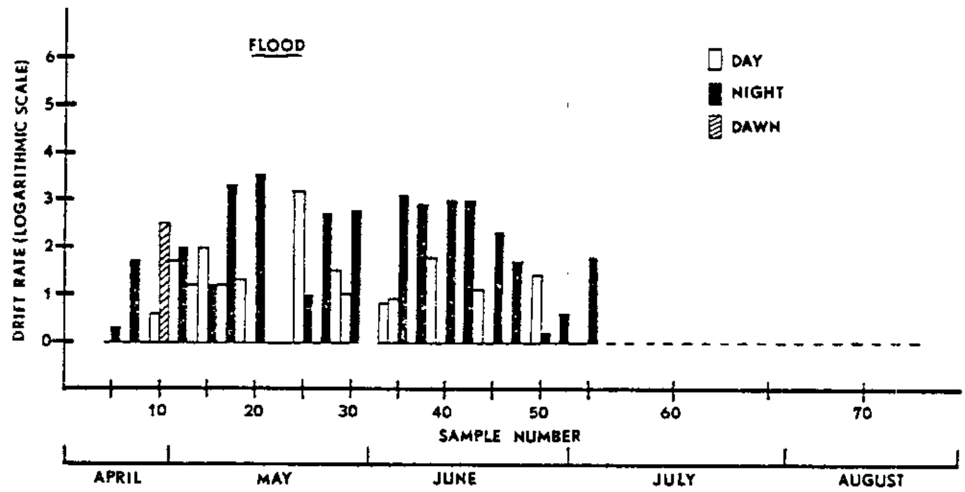


Figure V.B-7 (continued). Drift rate of protolarval fish collected in the vicinity of the Dickerson SES in 1978 (logarithmically transformed data). All species except the common shiner (*Notropis cornutus*) were included if represented by at least 10 specimens in drift samples. Sunfishes, though poorly represented, were also included because of the recreational value of the adults.

F. Tessellated darters (*E. olmstedi*)



G. All species

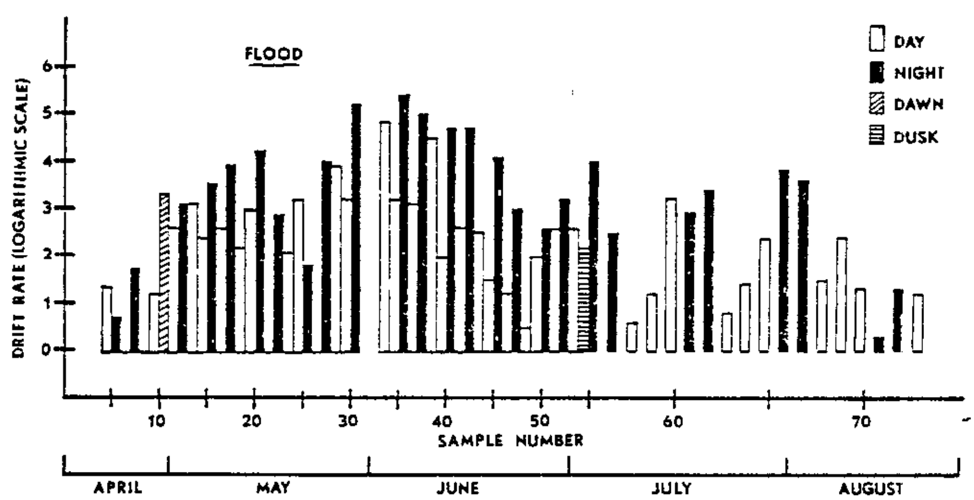
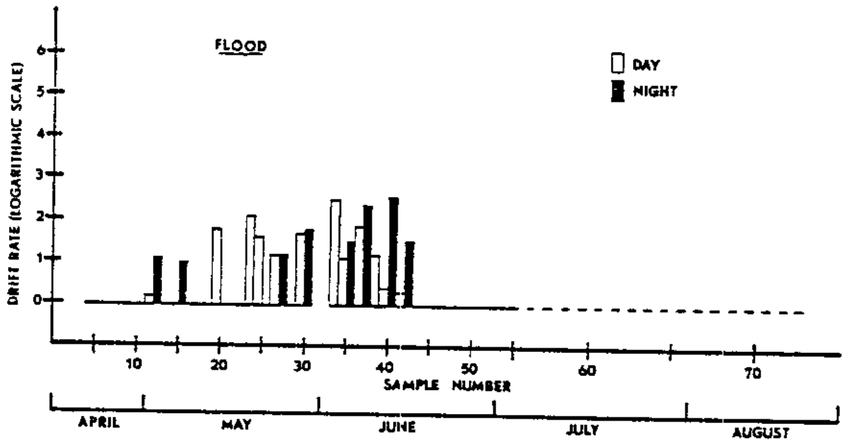
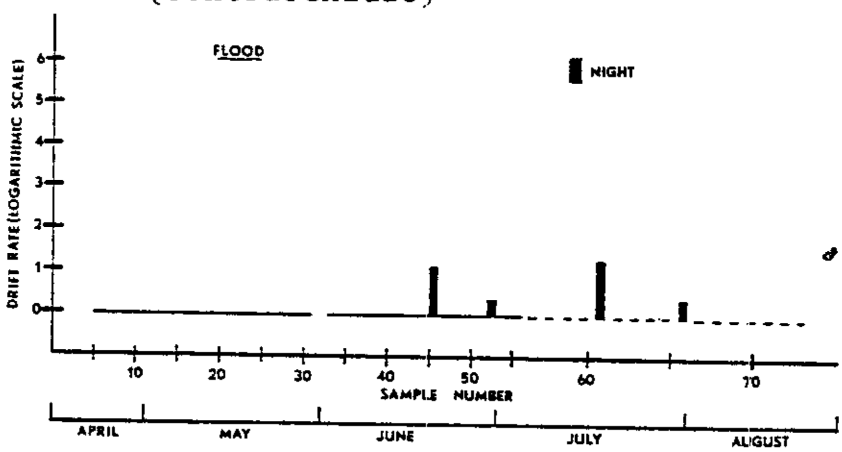


Figure V.B-7 (continued). Drift rate of protolarval fish collected in the vicinity of the Dickerson SES in 1978 (logarithmically transformed data). All species except the common shiner (*Notropis cornutus*) were included if represented by at least 10 specimens in drift samples. Sunfishes, though poorly represented, were also included because of the recreational value of the adults.

A. Suckers (Catostomidae)



B. Sunfishes (Centrarchidae)



C. All species

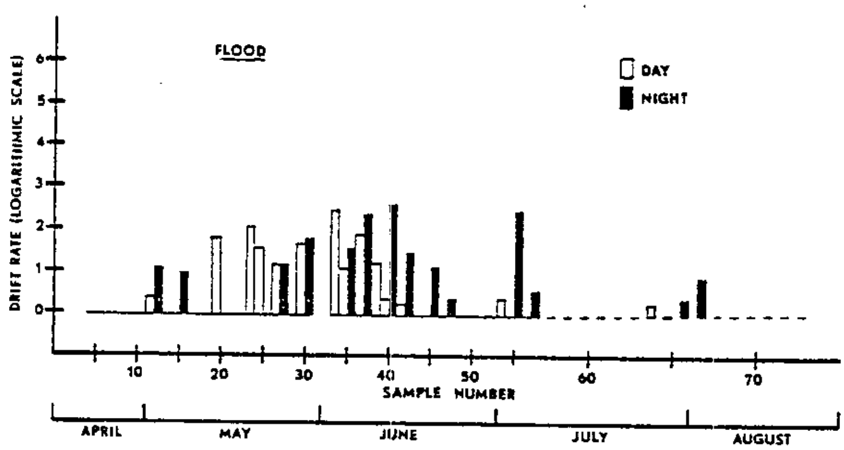
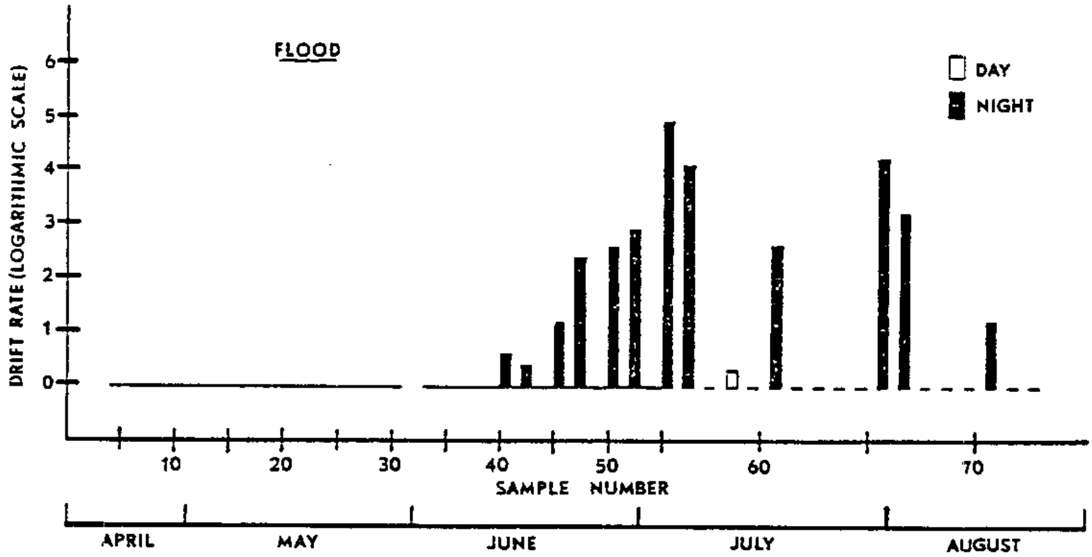


Figure V.B-8. Drift rate of mesolarval fish collected in the vicinity of the Dickerson SES in 1978 (logarithmically transformed data). Species are included if they are represented by at least 10 specimens in drift samples. Sunfishes, though poorly represented, are also included because of the recreational value of the adults.

A. Catfishes (Ictaluridae)



B. All species

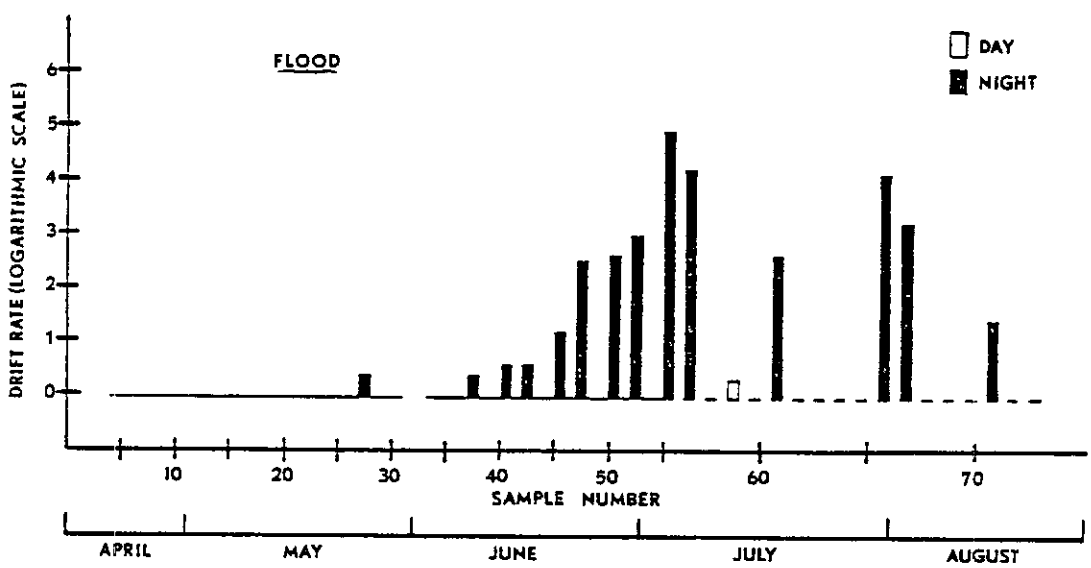


Figure V.B-9. Drift rate of metalarval fish collected in the vicinity of the Dickerson SES in 1978 (logarithmically transformed data). Species are included if they were represented by at least 10 specimens in drift samples.

past the plant and numbers of entrained individuals were obtained by adding weekly totals shown in Figure V.B-4; these estimates were 518 and 48 millions, respectively, which constitutes 10% of the drift (Table V.B-3). Numbers of juveniles were estimated to total two million in the drift and less than one million entrained. Division of these totals into the developmental phase and taxonomic category (Table V.B-3) reveals that six such categories represented about 90% of the specimens collected.

Some developmental and taxonomic categories were more or less evenly distributed in the near-shore and channel zones (Table V.B-3); for example, the lateral distribution coefficient for all eggs was 0.52 and that of channel catfish metalarvae was 0.50. (A coefficient of 0.5 indicates equal density of specimens in the near-shore and channel zones; a value of 1 indicates all specimens were collected in the near-shore zone.) Other species were more common in the near-shore zone; for example, the tessellated darter had a lateral distribution coefficient equal to 0.68.

Light intensity during daylight samples did not have a noticeable effect on drift and entrainment. Time of day within day and night periods also appeared unimportant. However, there was a strong difference between day and night samples for some taxonomic and developmental categories. The best example was that of metalarval catfish which drifted almost entirely at night as indicated by the high diel distribution coefficient (Fig. V.B-9 and Table V.B-3). All common larvae, regardless of developmental phase, were at least slightly more abundant in nighttime drift and entrainment samples (Figs. V.B-7-9). Eggs of spottail shiners were usually more abundant in night samples, while eggs of other species had a more uniform diel distribution or were more common in day samples (Fig. V.B-6).

The mean rate at which the SES pumped water from the river was 7.0% of the river flow. Entrainment was highest when there was a concurrent peak in drift and withdrawal rates (Fig. V.B-4). Changes in plant pumping rates were associated with changes in entrainment rates (Fig. V.B-10a). Calculated drift and entrainment rates of larvae were usually higher at night than during the day (Table V.B-3, Figs. V.B-5,7-9). Higher nighttime rates were also observed for *Notropis hudsonius* (spottail shiner) eggs except during the May flood (Fig. V.B-5b). Temporal variations in densities were similar in the river zones and the SES discharge (Fig. V.B-10b).

Densities of eggs and larvae (numbers per unit volume) were higher in the near-shore zone than in the channel zone or discharge canal (Table V.B-4). Before May 23, samples from the Maryland and Virginia near-shore zones were combined. During the remainder of the study, mean densities were 51 and 49 eggs and larvae per 100 m^3 and mean drift rates were 19 and 20 eggs and larvae per second in Maryland and Virginia near-shore zones, respectively.

Table V.B-3. Estimated drift and entrainment of common taxonomic and developmental categories of fish eggs, larvae and small juveniles collected at the Dickerson SES, 1978.

	Lateral Distribution (Coefficient)[1]	Diel Distribution (Coefficient)[2]	Seasonal Drift Total No. in millions	Seasonal Entrainment Total No. in millions	% of Drift entrained
Carp (*C. carpio*)					
protolarvae	0.66	0.59	64	5	8
Spottail Shiner (*N. hudsonius*)					
eggs	0.53	0.60	145	1	1*
protolarvae	0.66	0.63	92	17	19
Spotfin Shiner/bluntnose minnow (*N. spilopterus/P. notatus*)					
protolarvae	0.60	0.66	70	7	10
Channel Catfish (*I. punctatus*)					
metalarvae	0.50	0.99	46	1	3*
Tessellated Darter (*E. olmstedi*)					
protolarvae	0.68	0.74	39	6	16
All Species					
eggs	0.52	0.55	174	3	2*
protolarvae	0.60	0.61	278	39	14
mesolarvae	0.60	0.61	15	4	27
metalarvae	0.54	0.99	49	2	4*
juvenile	0.66	1.00	2	<1	6
Total			518	48+	10%

* Higher entrainment rates for these categories were expected based on plant pumping rates.

[1] A coefficient of zero indicates that all specimens were caught in the channel zone; a coefficient of 0.5 indicates an even distribution between near-shore and channel zones; a value of 1.0 indicates all specimens were caught in the near-shore zone.

[2] A coefficient of zero indicates that all specimens were caught during the day; a coefficient of 0.5 indicates a uniform diel distribution; a value of 1.0 indicates all specimens were caught at night.

Table V.B-4. Seasonal estimates of mean density and mean drift and entrainment of pooled taxonomic and developmental categories of fish eggs, larvae and small juveniles at the Dickerson SES in 1978.

	Near-shore Zone	Channel Zone	Discharge Zone
Mean density (No/100 m^3)	37	15	28
Mean drift rate (No/sec.)	16	34	-
Mean entrainment rate (No/sec.)	-	-	5

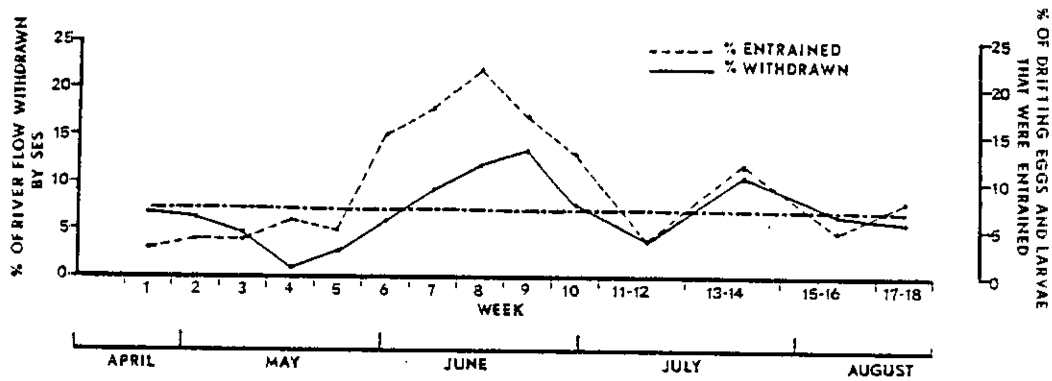


Figure V-B.10a. Comparison of mean weekly plant withdrawal rates of the Dickerson SES with mean weekly entrainment rates in 1978. The line at 7% represents the mean % of river flow withdrawn by the SES over the total sampling period.

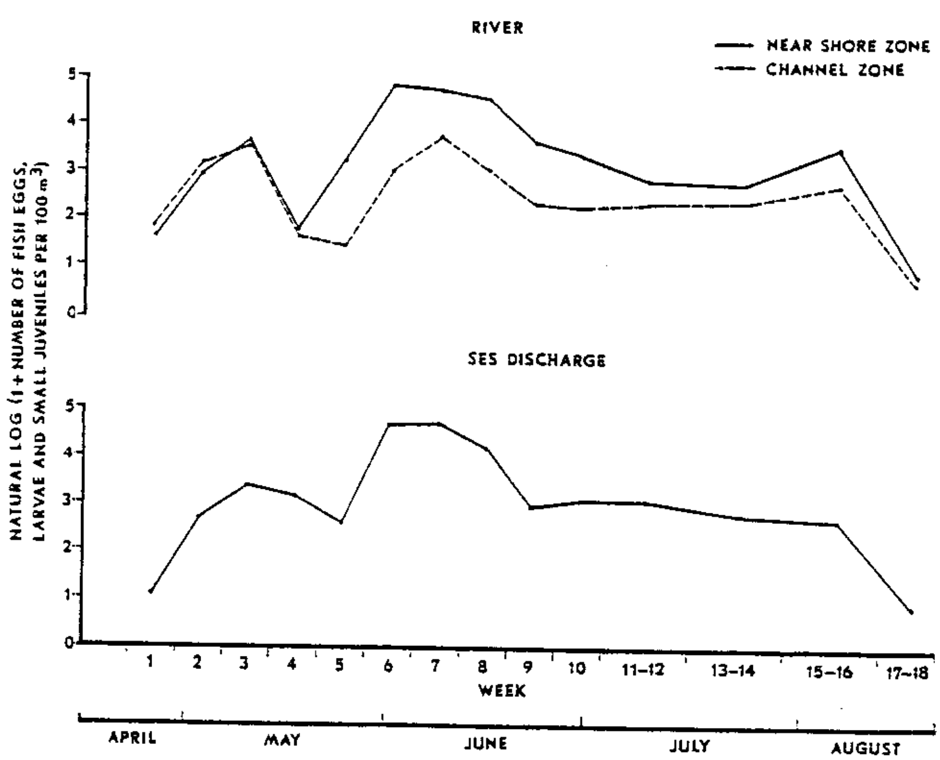


Figure V.B-10b. Comparison of estimated densities of fish eggs, larvae and small juveniles in river zones with densities in the Dickerson SES discharge in 1978.

With possible exceptions among catfishes, drift of eggs and larvae did not seem strongly related to flow or turbidity. Channel catfish drift estimates peaked during periods of high turbid flow (Fig. V-B-11), but the synchrony of peaks in abundance and these flow conditions may have been coincidental.

Entrainment Mortality Study

Data from mortality studies were contradictory. In the first of three studies, survival was high (about 87% of 558 larvae) after the 24-hour incubation period (Table V.B-5). In studies 2 and 3, survival after incubation was only 18% and 33%, respectively.

Turbidity and temperature may have contributed to the increased mortality. Turbidity during the first study was 12 JTU compared with 22 and 55-60 JTU in the second and third. Discharge temperature during the first study was about 89°F compared with about 93 to 94°F later.

Survival rate in the control sample collected during the third study was comparable to survival in the entrainment sample. Although sample size was small, this similarity suggests some mortalities noted in the entrainment samples may have been caused by handling of the larvae or natural mortality.

Shoreline Survey

The mean water temperature above the discharge was 24.1°C along straight banks and 20.6°C in cove areas. Below the discharge these values were 33.1°C and 32°7, respectively. The mean maximum water depth sampled was 0.5 m along straight banks and 0.4 m in coves; below the discharge these were 0.5 m and 0.3 m, respectively. Assuming an even slope to the water's edge the average water depth sampled was about 0.2 m. The area swept by the haul was 3.3 m^2, resulting in a volume sampled of about 0.6 m^3.

Above the discharge 55% of the hauls along straight banks and 86% of the hauls in cove areas were made over soft substrate (silt and/or detritus as opposed to sand and/or gravel). Below the discharge these percentages were 82% and 76%, respectively.

Numbers of specimens per haul were variable with a tendency for more protolarvae to be collected over soft substrates (Tables V.B-6 and 7). While sorting, it was noted that when a large quantity of detritus had been scooped up by the net, there was a tendency for many more protolarvae to have

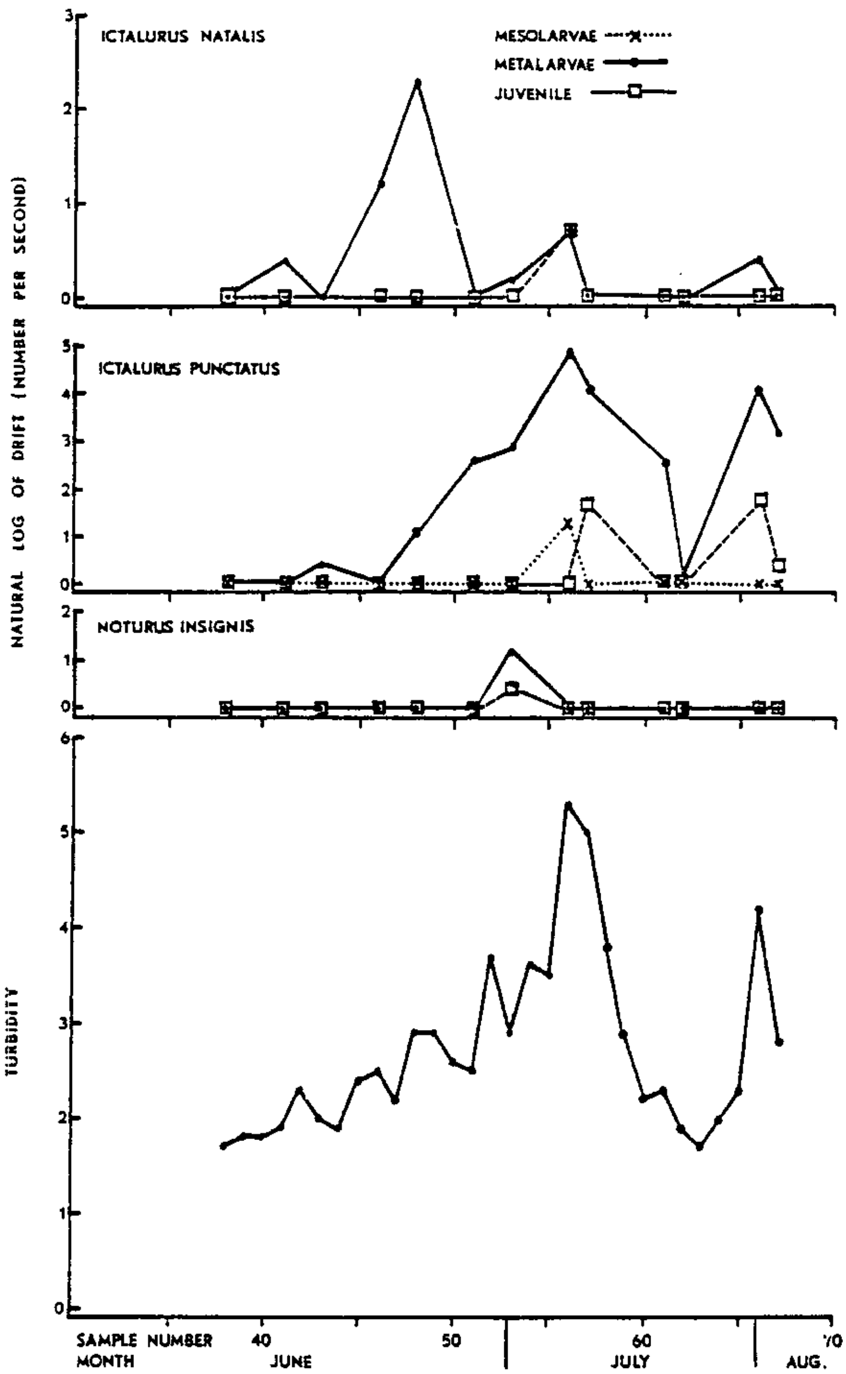


Figure V.B-11. Comparison of turbidity and estimated drift rate of catfish (Ictaluridae) larvae and juveniles collected in the vicinity of the Dickerson SES in 1978.

Table V.B-5. Survival rate of entrained larvae collected in the discharge of the Dickerson SES on three occasions in 1978 after a 24-hour holding period.

		Number alive/Number collected			
		1	2	3	4
collecting date:		Discharge 10-11 June[1]	Discharge 20-21 June[1]	Discharge 30 June-3 July	Control 30 June-3 July
Carp (*C. carpio*)	proto	58/66	4/10	0/10	None
Native minnow (*Cyprinidae*)	proto	262/288*	4/140	4/28	6/18
	meso	1/1			
	meta	2/2			
Sucker (*Catostomidae*)	meso	115/150	0/4	None	None
Yellow bullhead (*I. natalis*)	meta	None	12/15	2/3	0/2
Channel catfish (*I. punctatus*)	meso	None	5/5	None	0/1
Channel catfish (*I. punctatus*)	meta	1/1	6/12	16/21	None
Margined madtom (*N. insignis*)	meta	None	None	2/6	1/2
Redbreast sunfish (*L. auritus*)	meso	None	2/2	None	None
Tessellated darter (*E. olmstedi*)	proto	47/50	1/2	2/12	None
All species and developmental phases		486/558 (87%)	34/190 (18%)	26/80 (33%)	7/23 (30%)

[1] No control samples collected.

* Some dead specimens in this category were partly decomposed. Identification was difficult. Some misidentified carp or darters may have been included.

Table V.B-6. Cumulative catch frequencies (represented as a percent of the specimens caught) by environmental parameter for young fish collected along straight river banks with a fine-meshed seine in the vicinity of the Dickerson SES in August 1978. (The area sampled with each collection was approximately 3.3 m^2.)

Number of fish per collection	Catch frequency (% of total)							
	Bottom		Current			Depth		
	soft	hard	still	slow	moderate	0.5-1	1.5-2	2.5-3
	Protolarvae							
>16	17		29		13	14	13	
> 4	31		43	17	17	29	20	
> 0	66	8	86	58	29	48	53	25
≥ 0	100	100	100	100	100	100	100	100
	Mesolarvae							
>16	7		14		4	5	7	
> 4	21		43	8	8	14	13	13
> 0	55	23	71	58	79	52	27	50
≥ 0	100	100	100	100	100	100	100	100
	Metalarvae							
>16	21		43	17	4	14	13	13
> 4	34	38	71	17	33	38	27	38
> 0	72	54	100	58	63	76	60	63
≥ 0	100	100	100	100	100	100	100	100
	Juveniles							
>16	21	23	43	17	17	19	13	38
> 4	59	54	71	58	50	57	40	75
> 0	90	85	100	92	83	86	93	88
≥ 0	100	100	100	100	100	100	100	100
Number of collections	29	13	7	12	24	21	15	8

Table V.B-7. Cumulative catch frequencies (represented as a percent of the specimens caught) by environmental parameter for young fish collected in backwater areas with a fine meshed seine in the vicinity of the Dickerson SES in August 1978. (The area sampled with each collection was approximately equal to 3.3 m².)

Number of fish per collection	Catch frequency (% of total): Bottom, soft	Bottom, hard	Depth, 0.5-1	Depth, 1.5-3
Protolarvae				
>16	14		17	
> 4	27		33	
> 0	55		44	40
≥ 0	100	100	100	100
Mesolarvae				
>16	18		22	
> 4	36	17	44	10
> 0	55	33	61	30
≥ 0	100	100	100	100
Metalarvae				
>16	23		22	10
> 4	27	17	33	10
> 0	73	50	72	60
≥ 0	100	100	100	100
Juveniles				
>16	14	17	17	10
> 4	41	50	50	30
> 0	73	100	78	80
≥ 0	100	100	100	100
Number of collections	22	6	18	10

also been collected. This suggests that the larvae were on or close to the bottom and were collected more efficiently when the bottom of the net was below the substrate surface. The number of collections over hard and soft substrates was greater above the discharge than below it. The difference may have caused a slight bias.

The mean density of larvae along shore was 7.2 individuals per m^2. Catch frequency distributions and densities above and below the discharge were similar (Tables V.B-8 and 9). However, there were slight differences in the species composition: above the discharge, bluntnose minnows represented 33% of the mesolarvae, metalarvae and juveniles collected; below the discharge they represented about 2% (Table V.B-9). Spotfin shiner young were dominant in all areas; a few sunfish sp(p). were also collected (Table V.B-9).

Discussion

Drift and Entrainment Study

Drift and entrainment of the most common minnows and darters (spotfin shiner, spottail shiner, bluntnose minnow, tessellated darter, greenside darter) were composed primarily of protolarvae. All species seem to be entrained in greatest numbers shortly after they begin to swim.

Suckers were represented by more advanced larvae than were minnows and darters (Table V.B-1). While suckers hatch in the protolarval phase as do these other taxa, they differ by remaining buried in gravel while further development takes place. Catfishes were also represented by more advanced larvae. They hatch in the mesolarval phase and stay in nests guarded by parents (U.S. Fish and Wildlife Service, 1978).

Eggs of most local species were uncommon in drift and entrainment samples because they are firmly attached to a substrate, buried in gravel or laid in nests (Loos et al., in press; Breder and Rosen, 1966). Those of spottail shiners are attached to the surface of gravel and possibly Cladophora (Wells and House, 1974). Their abundance in the drift indicates that they are only weakly adhesive. Personal experience also indicates that eggs can easily be brushed from the substrate with the fingers. Drift and entrainment rates of spottail shiner eggs were several times greater than those of all other species combined.

There was less difference between day and night drift (and entrainment) for less developed larvae (protolarvae and mesolarvae) than for more advanced larvae (metalarvae). The

Table V.B-8. Comparison of catch frequencies of young fish of all developmental categories collected with a fine meshed seine above and below the discharge of the Dickerson SES in August 1978. (The area sampled with each collection was approximately equal to 3.3 m^2).

	Number of fish per collection	Catch Frequency (% of Total) Above Discharge	Below Discharge
Straight Bank	>64	14	4
	>16	38	43
	> 4	76	65
	> 0	95	100
	Number of collections	21	23
	Mean number of fish per collection	27	21
Cove	>64	14	14
	>16	29	29
	> 4	64	79
	> 0	93	93
	Number of collections	14	14
	Mean number of fish per collection	23	25

Table V.B-9. Comparison by taxonomic and developmental category of densities of young fish collected above and below the discharge of the Dickerson SES in August 1978.

	Mean number of fish per collection	
	Above Discharge	Below Discharge
Protolarvae	5	5
Mesolarvae	4	4
Metalarvae	6	6
Juveniles	10	7
Total	25	22
[1]Spotfin shiner	14	17
[1]Bluntnose minnow	6	<1
Lepomis sp(p).	<1	<1

[1]Protolarvae were not identified to species and are not included here. No protolarval *Lepomis* sp(p) were collected.

coefficient of diel variation for the former two was closer to 0.5 than to 1, while the coefficient for the latter approached 1 (Table V.B-3). (The coefficient of 0.5 indicates a uniform diel distribution; a value of 1 indicates that drift occurs only at night.) This relationship suggests the possibility that less developed larvae are relatively poor swimmers that cannot take good advantage of visual cues to hold their position, as more developed larvae can. One would expect that developmental and/or taxonomic groups having a higher relative drift rate in the day (the duration of which is about two times that of night) would drift at a higher rate (no./24 hours) relative to a given population size. Greater net avoidance also probably occurs during daytime collecting.

Eggs showed the smallest diel variation; nevertheless, more spottail shiner eggs were collected at night than during the day (Fig. V.B-5, Table V.B-3). Greater densities at night suggest nocturnal spawning, an aspect of spottail life history that has not previously been noted.

Differences in entrainment rates associated with developmental phases may be related to the lateral distribution of these phases. Roughly 14 to 27% of drifting protolarvae and mesolarvae were estimated to be entrained (Table V.B-3). Entrainment estimates for eggs were much lower. Protolarvae and mesolarvae tended to be more concentrated in the near-shore zone, i.e., the lateral distribution coefficient was equal to 0.6; thus, as expected, a greater portion of protolarvae and mesolarvae were entrained because the plant draws much of its coolant water from along the Maryland shore.

Channel catfish metalarvae (dominant metalarval species) were just as common in the channel as in the near-shore zone (i.e., the lateral distribution coefficient was equal to 0.5, Table V.B-3). Their low entrainment rate relative to drift may be partially explained by this uniform lateral distribution (Table V.B-3).

Seasonally pooled values for all taxonomic and developmental categories indicated greater density in the near-shore zone, while drift in this zone was less (Table V.B-3). These contrasting differences are a reflection of greater flow in the channel.

Entrainment rates are related to plant withdrawal rates (Fig. V.B-10a). Since eggs and larvae are found in both the channel and near-shore zones, the more water withdrawn by the plant, the more eggs and larvae will be taken in with it. During the first peak in "ichthyoplankton" drift rate in sampling weeks 2-4, plant withdrawal rates were modest compared with such rates during the second peak in larval drift in sampling weeks 6 to 8 (Fig. V.B-4). During two subsequent periods of increased drift in sampling weeks 11-12 and 15-16 there was no evident increase in entrainment as the plant withdrew a small portion of river flow during these periods.

It is possible to make a crude estimate of egg and larval entrainment rates without reference to biological samples. If one assumes drifting eggs and larvae are uniformly distributed across the width of the river and if their temporal distribution were the same throughout the period when drift occurred, then the entrainment rate would be the same as the mean plant withdrawal rate, i.e., 7.0% (Fig. V.B-10a). That this value does not differ greatly from the 10% entrainment rate estimated from plankton net sampling is due to under- and over-estimates for groups with different distribution patterns.

Drift and entrainment were calculated as a function of river flow and plant pumping rates. Therefore one would expect a relation between river water withdrawal rates and entrainment rates (Fig. V.B-10a). However, during the maximum drift observed (in weeks 6 to 10) entrainment was more than expected based on withdrawal rates. During this period densities in the near-shore zone, where the plant draws most of its water, exceeded channel zone densities to a greater extent than before or after this period (Fig. V.B-10b). Except during the May flood (in study weeks 4 and 5) densities in the discharge were usually similar to those in the near-shore zone.

Comparison of rates at which the SES pumped water from the river with rates of entrainment for specific taxa and developmental categories was less satisfactory than comparison of pumping rates with overall entrainment rates for all categories. One would expect partitioning of the sample in this way to lead to greater sampling error. Discrepancies in entrainment estimates from expectations based on withdrawal rates made it necessary to arbitrarily choose which comparison was more realistic.

While it was estimated that 1% of spottail shiner eggs were entrained (Table V.B-3), the mean plant withdrawal rate at the time they were present in the river was 5%. As there is no reason to assume that these eggs would not be entrained at a rate proportional to the withdrawal of river water, it is best to place entrainment estimates closer to 5%.

The estimated entrainment rate for spottail shiner protolarvae was 19% (Table V.B-3). During the period from sample 28 to 46 when these larvae were common in the drift (Fig. V.B-7) and when entrainment rates were highest (Fig. V.B-4) the mean withdrawal rate was only 9.4%. In this case, the higher rate is assumed closer to reality because concentration of larvae in the near-shore zone should have lead to more entrainment. Entrainment rates for protolarvae and mesolarvae were generally greater than expected based on pumping rates alone.

Metalarval catfishes, like adults, may be more active at night (Fig. V.B-9). Nocturnal activity might result in greater nocturnal drift.

During periods of high flow and turbid water in June and July, channel catfish drift peaked (Fig. V.B-11), which suggested one or both these factors might be related to drift. However, data were scanty and no rigorous analysis was possible. Effects of high flow and turbidity are probably mixed, as they might decrease spawning activity while at the same time increasing the portion of the population that is drifting. It was not feasible to monitor spawning activity or overall egg and larval population size.

Drift of channel catfish metalarvae peaked during samples 50-61 and 66-67 (Fig. V.B-11). The mean plant withdrawal rates at the time these samples were collected was 6.3%, while estimates of larval entrainment were only 3%. It is assumed that the 6.3% figure is more accurate because channel catfish metalarvae were evenly distributed across the river and, therefore, one would expect them to be entrained at rates proportional to plant pumping rates.

Entrainment Mortality Study

Turbidity may have been a complicating factor in this study because the plankton net concentrated silt and detritus as well as larvae. This material may have contributed to mortalities by smothering larvae.

Higher ambient river temperatures during the last two studies may have contributed to mortalities.

Shoreline Survey

Shoreline densities above and below the discharge were compared with each other and with that of drifting larvae. (Drift data were collected from August 12 to 20 during the week prior to the shore survey (August 21 to 23). One might criticize the validity of such a comparison because changes could have occurred in the interim. However, differences between larval densities along shore and densities of drifting larvae were quite large so that limited conclusions from the data are warranted.)

Mean densities of drifting young during this collecting week were 1.45 individuals/100 m^3. As the mean depth at the time was 1.5 m, this density is equivalent to 0.022 larvae per m^2, about 700 times less than measured at the shoreline (7.2 per m^2) or about 1800 times less on a unit volume basis. If this comparison is limited to protolarvae, the differences would be 140 and 360 times, respectively. It had previously been concluded from qualitative observations (ANSP, 1974) that larvae congregate along shore; these data support that conclusion.

Although densities are high at the shoreline, the area along shore is small compared with the rest of the river; therefore, a comparison based on numbers of fish found in the area rather than on their density is less extreme.

Evaluation

A literature survey by Carrier (1978) indicates that it is possible to demonstrate absence of major entrainment impact when: local or regional distributions of larvae are such that only a small portion of their populations are found in the vicinity of a plant; entrainment is small in relation to population size; and/or mortality rates of entrained larvae are minimal. A number of mathematical models have been developed to aid in impact assessment; however, even relatively simple ones (e.g., Goodyear, 1978) require life history data unavailable for fishes in the study area.

At Dickerson there was no measurable entrainment of sport fish eggs. Entrainment of their larvae was small: bass were not collected in any samples, few other centrarchids were collected, and only about 6% of drifting channel catfish were estimated to be entrained. Other studies (King, 1978; Wrenn, 1976) have indicated that relative abundance of drifting larvae does not necessarily correspond to relative abundance of adult fish present in an area. The nesting behavior of centrarchid species (sunfish and bass) probably helps reduce their occurrence in the drift and so might reduce entrainment.

The majority of fish entrained were forage species; they were more common in the near-shore zone where they were more vulnerable to entrainment.

Because of contradictory results, data from mortality studies were not useful for quantitative evaluation of plant mortality on entrained larvae. However, it should be noted that on June 10, 1979, during the week of highest drift and entrainment rates (Fig. V.B-4), a mortality study indicated 87% survival of entrained larvae (Table V.B-5). Later (on June 22 and June 30 to July 2) while drift and entrainment rates were relatively low, survival rates as low as 18% were observed.

The conservative course is to assume a large mortality rate among those entrained. In that case it seems possible that the estimated entrainment rate (e.g., 19% for drifting spottail shiner larvae) might be large enough to reduce stocks of adult fish.

Further, two points of circumstantial evidence suggest that drift in the area of the intake is small. The first is based on qualitative differences between young fishes concentrated along the shoreline and those in discharge samples. Any young fish drifting along the edge of the river above the plant should be drawn into the intake structure and should be represented in these samples. The shoreline area contained many mesolarval and metalarval spotfins while very few in these categories were entrained. The second point is based on larval density measured in the discharge canal which was intermediate to that in channel and near-shore zones. If drift in the shoreline area had been noteworthy, densities in the discharge should have been larger.

In the shoreline survey, it was inferred that most of the protolarvae in that area were found on or near the bottom. Such a distribution would greatly reduce protolarval drift. This evidence suggests that a large segment of the forage fish population is found along the shoreline where drift and therefore vulnerability to entrainment is minimal.

The shore survey data indicated that densities of young spotfin shiner were similar above and below the discharge; fewer bluntnose minnow mesolarvae, metalarvae and small juveniles were caught below the discharge, but numbers in these categories were small in both areas (Table V.B-9). If this difference in the catch of bluntnose minnow young reflects a real population difference, it might have been caused by a shift in spawning season and/or avoidance of heated water by potential spawners.

A previous qualitative study of larval distribution along shore from April to July, 1973, indicated similar numbers of species were found above and below the discharge (ANSP, 1974).

Conclusions

Plankton net collections were used to estimate drift and entrainment of eggs, larvae and small juveniles. All phases of the diel cycle received approximately equal representation. Samples were collected frequently so that nearly all environmental conditions that occurred during the study period were represented. Drift was estimated for the near-shore zone (from near the river margin to 30 m from each shore) and the channel zone (the remaining width of the river). Estimates were calculated from larval densities and flow rates. Entrainment was estimated from plant pumping rates and larval densities in discharge.

It was estimated that the plant entrains about 10% of the drift; the percentage of eggs entrained was less than 10% while that of larvae was higher. Overall, densities tended to be higher in the near-shore zone, where the plant draws its coolant water, so entrainment rates were higher than they would be if the lateral distribution of the drift were more even. Altogether it was estimated that 48 million eggs and larvae (and less than one million juveniles) were entrained during the study period.

Data from mortality studies were contradictory and not considered useful in evaluating possible impacts of entrainment. However since entrainment of sport fishes was low, little effect on their populations would be expected.

Samples for determining densities of larvae at the shoreline were gathered with a fine-meshed seine in late August when larvae of the spotfin shiner (a major forage fish) were dominant. These data indicated that the shoreline was an area where densities of young were much higher than in the rest of the river. Circumstantial evidence indicated little drift in that area; therefore, a large portion of this forage fish population was probably not vulnerable to entrainment. Densities of young spotfin shiners in the shoreline area above and below the discharge were similar. It was concluded that entrainment probably had a minor impact on sport fishes and on at least one important forage fish.

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VI. SUMMARY AND CONCLUSIONS

Hydrothermal studies included both thermal mapping (during primarily low-water conditions in the summer of 1977) and formulation of the Dickerson Temperature Model (DTM), which describes 7-day average temperatures for a period of 10 years (1967-1977). Both studies indicate that the Dickerson SES appears not to be in compliance with the Water Quality Criteria of the State of Maryland. The median distance downstream to the 2°C isotherm, estimated by the mapping studies, was more than 20 km (which is in excess of the allowable 6-h flow); the average lateral extent was 64% of the river. The DTM predicted that the SES appears not to be in compliance during at least a portion of all seasons; however, the greatest percentage of time of non-compliance, according to the DTM, occurs during the summer and fall. 1

Biological studies carried out from 1956 through 1977 showed considerable variation with regard to long-term trends in the entire study area as well as station differences indicating some plant impact in certain areas. Qualitative surveys (1956-1975) and the quantitative diatometer study (1966-1976) showed that there has been a decrease in the number of species collected in the area. Long-term declines in species collected have been evident for algae (as seen in both qualitative and quantitative studies), insects and non-insect macroinvertebrates. Although there has been an increase in silt- and eutrophication-tolerant species (within some taxonomic groups), there is no evidence linking the decline in species with siltation (sedimentation) or eutrophication. Because the decline in species has occurred at several stations upriver from the plant, it can be inferred that these changes are not related to the operation of the Dickerson SES. 2

The differences between the numbers of species collected at stations heated by the plant discharge and at control stations have varied among surveys and among groups (trophic levels). 3

Bacterial surveys showed no consistent trends that would have indicated a plant-related effect on bacterial abundances. 4

Protozoa survey data indicated no long-term decrease in species as was found with some of the other groups. Spring survey data showed no impact, but summer/fall survey data indicated that there were fewer species collected at Station 2L (just below the plant discharge, on the same side of the river as the plant) and Station 2R (below the plant discharge, across the river from Station 2L). However, reductions at 2R appeared to be related, in part, to flow conditions at the station. 5

Diatom survey data showed a clear reduction in the numbers of species collected at all stations (including control stations) from 1956 to 1974. The plant did not cause a further reduction 6 in species number at Station 2L, directly below the plant discharge.

The non-diatom algae survey data showed a possible plant impact on only one occasion (the summer survey in 1960). Most of the surveys indicated that Station 2L (directly below the discharge) yielded more species than Station 2R (across the river from Station 2L). It is interesting to note that Station 2L maintained a balance between green and blue-green algae, while a trend was noted toward increased blue-greens and a decrease in greens at Station 2R and other stations. In addition, there was a long-term decrease in the numbers of species collected in the entire study area.

The insect surveys showed tremendous variation from year to year with regard to station differences. During some years, Station 2L yielded the most species while at other times it had the fewest species. However, there is no evidence that the heated effluent was causing a decrease in the number of insect species collected below the plant.

The non-insect macroinvertebrate surveys indicate that there has been a decrease in the number of pollution-sensitive species over the years at Station 2L compared with other stations. There have been sporadic reductions of species overall at this station, but there is no consistent trend indicating a plant impact. The drastic decrease in the number of species in the entire collecting area would indicate that any possible plant impact is slight compared with these overall changes in the area.

The fish surveys showed no apparent plant impact. It is interesting to note that there has been no long-term decline in the numbers of fish species collected in the entire study area, as was found at most other trophic levels. Fish evidently have not been affected by the factors responsible for the decline in these other groups.

The quantitative diatometer studies indicated both short-term (seasonal) and long-term plant impacts. Growth of diatoms in the plume is stimulated in cool months and inhibited during hot months. Although there is no direct quantitative evidence, it is thought that there is quick recovery a short distance below the plant because the differences in growth in and out of the plume are not severe.

The long-term impact is reflected in the steady decline in the number of species below the plant. Although there has been a 30% decrease in species at the control area, the decrease in the impact area is greater (35%). The decrease in the numbers of species of diatoms determined by the diatometer studies is in agreement with the long-term decrease in diatom species observed at all stations in the diatom surveys.

The conclusion drawn from the diatometer studies (with regard to long-term trends) is that when the river is already stressed, additional stress such as thermal elevation aggravates the progressive decline in species richness.

The quantitative insect studies indicated more impact by the plant than was observed for any other group investigated. The 1975 artificial substrate study showed a possible decrease in insect species and individuals below the plant. The 1976 artificial substrate study indicated a decrease in species diversity and abundance 1/2 km below the plant compared to 1 km above the plant. The decrease was not detectable 2 km below the plant. The artificial dome study (1976) showed great variability between stations. Although there was a significant decrease in abundance of insects below the plant, there was a similar decrease at a station located outside of the influence of the plume. It is difficult to ascribe the decrease below the plant to the thermal discharge in light of the low numbers found in control areas during the dome study.

The impact of the SES on the insect assemblage below the plant was much more evident from the 1977 studies. A more detailed artificial substrate study revealed significant distributional differences with regard to the plant discharge. Most noticeable was the reduction in numbers of taxa and abundance of insects immediately below the discharge. However, the observed reductions were localized, extending no farhter than about 3 km downstream of the discharge.

A study of the selected RIS *Potamyia flava* showed distributional differences indicating possible adverse plant impact. There was a decrease in abundance immediately below the plant; however, the numbers increased farther downriver from the area of depression, indicating a localized impact on this species.

An analysis of the distribution of early larval stages (instars) of *Potamyia flava* also gave indications of a plant effect. The population structure of *P. flava* in the heated waters below the plant discharge differed from the populations collected at other stations. In the heated waters the earlier instars were predominant. At other stations the distribution of instars was more balanced.

A third indication of plant impact was the difference in growth of individuals in subpopulations at control and mixing zone stations during 1976 and 1977. A small but statistically significant difference in head capsule width was observed between the two subpopulations.

The extent of the plant impact determined by the quantitative insect studies appears to be localized. Although the studies were not extended downriver to an area outside the mixing zone, "recovery" appears to be occurring within the study area.

The quantitative fish studies have been summarized by season and by collection technique (seining and electrofishing). In general, during the fall, winter and spring there were more species and individuals collected in the heated waters than in control areas. Resident Important Species "attracted" to the plume during these seasons were channel catfish, spottail and some of the sunfish (*Lepomis* sp.). Smallmouth bass growth was enhanced in the plume during the spring and carp spawning increased.

The influence of the plant on fish in the summer and early fall is complex. The 1975 electrofishing study indicated a decrease in species and specimens at Station 2AL (closest to the discharge, downstream on the same side of the river as the plant). Three RIS, spottail, redbreast and largemouth bass, were absent or rare. Many channel catfish collected in the plume were ulcerated in the 1975 survey only. The 1976 electrofishing study showed the fewest species at Station 2AL. Of the RIS, redbreast was less abundant at 2AL than elsewhere; however, spottail, channel catfish and pumpkinseed were most abundant in the plume.

A comparison of the three years of seining studies revealed no consistent trend in the abundance of fish or fish species collected at the various stations. Station 2AL yielded the fewest species in 1974, the fourth fewest in 1976 and the second fewest in 1977. Comparison of the numbers of individuals shows that Station 2AL was lowest in 1977, but not in 1974 and 1976. However, the 1974 reduction in numbers seen at Station 2AL (just below the discharge) was equaled by the decrease in numbers at a station above the plant. A study of spotfin shiners showed an increase in condition factor below the plant. However, additional studies are needed to determine the influence of the plant as previously published studies have described decreases in the condition factor of fish collected in the heated waters below a power plant.

Overall, the studies indicate a redistribution of certain fish with regard to the location of the heated waters from the SES. This can be seen as different seasonal responses of fish abundance to the thermal discharge, in general an attraction in winter, (based on data for one year only), and a repulsion in summer; changes in species composition according to temperature preferences; and enhancement of winter fishing. In the case of carp, a possible alteration of life history features might be occurring as reflected in increased spawning in the heated waters during spring.

An estimate of the exclusion of fish by lethally high temperatures was made for eight species, four of which were RIS. This was done by comparing published lethal thresholds with the predicted temperatures in the river for each season. No fish were predicted to be affected during winter or spring, and thermal exclusion was found to be more common in the summer than in the fall.

A wide variation in predicted areas and times of exclusion was exhibited by the species investigated. Redhorse was predicted to be excluded to the greatest extent, followed by largemouth bass; smallmouth bass; channel catfish, carp and spotfin shiner equally; longear sunfish and then pumpkinseed. Exclusion was almost always limited to the left (east) one-fifth of the river, but extended downriver as much as 21 km for 39.8% of the summer (redhorse). For most species, however, the areas of high exclusion (by percentage of time) were fairly localized, i.e., 1 to 3 km of the left (east) one-fifth of the river downstream from the discharge.

Maximum weekly average temperatures (MWAT) for growth and reproduction for six species of fish were compared to the thermal model of the Dickerson SES plume. Smallmouth bass were predicted to be the most seriously impaired in growth (in summer); the MWAT value was exceeded 72.6% of the time in the hottest waters (to 1 km below the discharge). As far as 21 km downstream, the MWAT value was exceeded 28.4% (right bank) to 39.8% (left bank) of the time.

MWAT values for reproduction were exceeded for considerable periods during spring. However, suitable spawning temperatures range widely. Therefore, the most probable impact of the heated discharge on spawning would be a localized shift in the time of spawning. Therefore, the frequently exceeded MWAT values for reproduction are not interpreted to indicate a substantial reduction in spawning at plume locations.

Overall, there appear to be plant-related impacts in the form of differences in the distribution (real and predicted) of fish in relation to the thermal plume, altered spawning activity (real and predicted) by the plume, and plume-related altered growth. The observed impacts appeared to be localized; predicted impacts of thermal exclusion, reduced growth and spawning activity extend considerably farther downriver for some species.

As with the other quantitative studies, i.e., insects and diatoms, no fish collections were made outside the mixing zone. However, in most cases, the impacts are localized within a few kilometers downstream of the discharge. It is interesting to note that the apparent impact is confined to an area within the allowable mixing zone of 6-h flow even though the Dickerson plume extends farther downstream. Because of the localized area of impact and an apparent "recovery" within the study area, it is considered that the impacts should not be judged significant as defined by the Maryland Water Quality Regulations. Because there have been no significant adverse impacts on the usability of these waters for future industrial, commercial fisheries (none exists there at present), sport fisheries, or other recreational use, it is also considered that there has been no adverse impact on the beneficial uses of the river over a 5-year period.

A 12-month impingement study showed that relatively low numbers of fish were impinged throughout the year (0-600 fish impinged/24 h) with the exception of a peak of over 8,000/24 h in March and almost 3,000/24 h in May. The estimated monetary value for the total number of fish impinged in one year is $11,282 (as determined by procedures outlined in COMAR 08.02.09.01).

An entrainment study provided an estimation of 48 million eggs and larvae and less than one million juveniles entrained by the plant. This represents about 10% of the drift in the Potomac River. Data from mortality studies were not conclusive in evaluating possible impacts of entrainment on the river. However, since entrainment of sport fishes was low, there should be little effect on their populations.

The conclusion drawn from the material presented in this document is that the Dickerson SES appears to have an impact on the biota of the Potomac River; however, the effect is localized within a 2.5-km area, not extending beyond the mixing zone of the thermal discharge. Therefore, it is the opinion of the Academy of Natural Sciences of Philadelphia that the Dickerson SES qualifies for alternate effluent limitations in compliance with the Federal Water Pollution Control Act and Maryland Water Pollution Control Regulations.

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Hydrothermal studies
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